NET PRODUCTIVITY OF EMERGENT VEGETATION AT HORN POINT SALT MARSH

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ABSTRACT

Title of Thesis: Net Productivity of Emergent Vegetation at Horn Point Salt Marsh

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Analyses of monthly standing crop, daily rates of production, and variations in yearly productivity for 5 major vegetation zones and estimations of underground production for the *Spartina patens*/*Distichlis spicata* mixture were conducted over two consecutive growing seasons for a Chesapeake Bay brackish marsh. Regression models for plant height and dry weight biomass were generated for all seasons of the year and covariance analysis demonstrates that the relationship between height and dry weight within each species is the same for all seasons of the year except in the species *Spartina alterniflora* and *Phragmites australis*. Positive correlation coefficients ranged from .27 for *S. alterniflora* to .96 for *P. australis* with the other species having intermediate values. Overall, production at Horn Point is lower than most other values in the literature with the 2-year average value for *S. alterniflora* (676 g/m^2) being $\frac{1}{2}$ the average for the Atlantic Coast but the 2-year average

for *S. patens* (628 g/m^2) being slightly higher than its Atlantic Coast average. On a square meter basis, the primary producers rank in the following order of importance for the two year average of standing crop: *Typha angustifolia* (985 g/m^2), *Phragmites australis* (892 g/m^2), *S. alterniflora/Amaranthus cannabinus* (676 g/m^2), *S. patens/D. spicata* (628 g/m^2), and *Hibiscus moscheutos* (~~516~~ 531 g/m^2). D.R.C. 6/7/78 However, the most important zones in terms of areally weighted production (in metric tons) for 1973 at Horn Point Marsh are the *S. patens/D. spicata* (7.61), *H. moscheutos* (5.07), *S. alterniflora/A. cannabinus* (3.22), *P. australis* (0.659), and *T. angustifolia/H. moscheutos* (0.644).

In the brackish marsh (*S. patens/D. spicata*) exclosure experiments demonstrated that almost 100% of the net primary production (NPP) passes through the detritus food chain but in the contiguous fresh marsh (*H. moscheutos*) 37% of the NPP is utilized by the grazing food chain. Underground production for *S. patens/D. spicata* was determined by an experimental approach involving transplantation of underground material and a dry weight shoot:root ratio of 1:16 was determined over a twelve month period. An efficiency rate for conversion of visible solar radiation to plant production in 1974 ranged from 0.11% for *H. moscheutos* in the *Typha/Hibiscus* zone to 1.12% for the *Typha angustifolia/Hibiscus moscheutos* mixture.

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I would also like to thank Dr. Peter Wagner, Director of the University of Maryland Center for Environmental and Estuarine Studies (UMCEES) and the staff members and Professor in Charge, Mr. Paul Winn, of the Horn Point Environmental Laboratory for their assistance and use of the facilities.

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INTRODUCTION

Estuaries are among the most highly productive ecosystems of the world (Odum, 1971) and increasingly in recent years have become recognized as an invaluable component of nature. Probably the world's best and largest example of a drowned river valley estuary is the Chesapeake Bay. For the Chesapeake Bay and any other estuary the salt marsh is a fundamental part, however little has been done in Maryland to evaluate the productivity of salt marshes along the eastern shore of the Chesapeake Bay. This is surprising since 91,000 hectares (227,000 acres) or 70% of the 131,500 hectares (325,000 acres) of total Chesapeake Bay marshland are located there. For this reason, a study of aerial and subterranean productivity of emergent marsh vegetation was conducted at Horn Point Marsh on the eastern shore of the Chesapeake Bay in Dorchester County.

This study is a comprehensive analysis of seasonal productivity of a mid-Atlantic brackish marsh spanning a 16 month period from March, 1973 to July, 1974. To document long term changes in productivity of dominant plant species in Horn Point Marsh and to accurately evaluate annual production on a monthly basis for ecosystem modelling, eleven standing crop estimates of net community production (NCP) have been made over two consecutive growing seasons. In addition, average height values were recorded for all vegetation types for one year from July, 1973 to July, 1974 and a least square regression model has been generated for height versus dry weight biomass. This technique has been demonstrated to be an accurate estimation of productivity for marsh vegetation for at least the peak of the growing season. In North Carolina marshes, Stroud and Cooper (1971) reported that a high correlation (+.94) exists between height and dry weight biomass for *Spartina alterniflora* and Williams and Murdoch (1968) also found a good correlation between height and log transformed standing crop values for this species. Nixon and Oviatt (1973a) found a similarly high correlation of +.89 between log weight and height of *S. alterniflora* in Rhode Island. However, Broome, Woodhouse, and Seneca (1973) found a significant relationship but low correlation (+.26) between height and weight for *S. alterniflora* in mineral nutrition experiments. Therefore one objective of this study was to determine the degree of relationship and to construct a regression model for these variables for use in future productivity studies in the Upper Chesapeake Bay region.

An experimental approach was used to estimate underground production for *Spartina patens* and *Distichlis spicata* which involved transplantation of underground rhizome mat. Also, net primary productivity (NPP) estimates were made by use of grazing exclosures for the *S. patens*/*D. spicata* and *Hibiscus moscheutos* zones. Estimations of NCP and NPP were made in order to assess this marsh's contribution to its two basic food webs. The primary consumers of the first web are herbivores, in this case insects, birds, and presumably muskrats feeding on Spartina and Juncus rhizomes and leaves (Higman, 1972). This creates a non-continuous transformation of energy due to the consumers' seasonal changes in feeding habits as well as feeding rates. The primary consumers of the second web are algal and detritus feeders. The energy flow of this web is a continuous, year-round process and is based on a major portion of the primary production of the marsh. The importance of determining the relative magnitude of these two webs is obvious, since it is crucial in assessing the relative inputs of marsh plants into the adjacent aquatic ecosystem of a salt marsh (Teal, 1962).

Productivity estimates for Atlantic and Gulf Coast salt marshes have been carried out in most states (summaries given by Keefe, 1972; Woodwell, Rich, and Hall, 1973; de la Cruz, 1973) but with few estimates for Maryland. Table I sets forth a comprehensive and updated list of productivity values for the dominant marsh species of eastern North America.

It is therefore the purpose of this study to (1) provide an insight into the characteristics of yearly production for a small, irregularly flooded, mixed-species salt marsh and (2) to aid in understanding annual variations in salt marsh productivity and (3) to make long term estimates of productivity easier to predict.

TABLE I. A SUMMARY OF HEIGHT (CM), STANDING CROP (G DRY WT./M^2), AND NET PRODUCTION (IN PARENTHESES) FOR THE DOMINANT SALT MARSH SPECIES OF THE ATLANTIC AND GULF COASTS OF NORTH AMERICA

Region	Species	Height	Biomass	Reference
Ontario, Can.	*Phragmites australis*	265		Bayly & O'Neil, 1972
Nova Scotia	*Spartina alterniflora*		580	Mann, 1972
Minnesota	*Typha latifolia*		1360	Bray, 1962
Rhode Island	*Spartina alterniflora*	112	433-1383	Nixon & Oviatt, 1973a
	Providence River	125	946	"
	Upper Bay		1017	"
	Lower Bay	113	714	"
	Block Island Sound		476	"
	S. alterniflora Tall		840	Nixon & Oviatt, 1973b
	S. alterniflora Short		432	"
	Spartina patens		430	"
	S. patens/Distichlis spicata		680	"
	Typha latifolia		693	"

TABLE 1. CONTINUED

Long Island	*Spartina alterniflora*	Tall	127	827	Udell et al., 1969
	Spartina alterniflora	Short	28.7	508	"
	Spartina patens		25.4	503	"
	S. patens			993	Harper, 1918
	Distichlis spicata		33	647	Udell et al., 1969
	Phragmites australis			2695	Harper, 1918
	Typha latifolia			1358	"
	Typha angustifolia			1733	"
New Jersey	*Spartina alterniflora*			300	Good, 1965
	S. alterniflora	Tall	142.7	1182	Potera & MacNamara, 1972
	S. alterniflora	Tall		1700	Good, 1972
	S. alterniflora	Tall	145	1592	Squiers & Good, 1974
	S. alterniflora	Medium		621	Good, 1972
	S. alterniflora	Short	25	592	Squiers & Good, 1974
	S. alterniflora	Short		590	Good, 1972
	S. patens			550	Good, 1972
	Distichlis spicata			670	Good, 1972

TABLE 1. CONTINUED

Delaware	Spartina alterniflora	445	Morgan, 1961
	S. alterniflora Dwarf	448*	Sullivan & Daiber, 1974
Maryland	Spartina alterniflora	1207	Johnson, 1970
	Spartina cynosuroides	906-2142	Flemer et al., 1973
	Spartina patens/Distichlis spicata	680	"
	Typha angustifolia	934-2338	"
	Typha latifolia	966	Johnson, 1970
	Phragmites australis	1451	"
	P. australis	811-1992	Flemer et al., 1973
Maryland-Virginia	Spartina alterniflora	427-558	Keefe & Boynton, 1973
Virginia	Spartina alterniflora	467	Mendelssohn & Marcellus, 1971
	S. alterniflora	546	"
	S. alterniflora	356	"
	S. alterniflora Tall	1570-1752	Wass & Wright, 1969
	S. alterniflora Short	695-920	"
	Spartina patens	805	"

* Value has been adjusted 71% lower to convert fresh to dry weight

TABLE 1. CONTINUED

	Juncus roemerianus		650		Wass & Wright, 1969
	Distichlis spicata		360		"
	Spartina cynosuroides		1456		"
North Carolina	*Spartina alterniflora*				
	High Marsh		250		Williams & Murdoch, 1966
	Streamside		2100	(1000)	"
	S. alterniflora Tall		1171	(1563)	Stroud & Cooper, 1969
	S. alterniflora Tall	160	1300		Marshall, 1970
	S. alterniflora Tall		1019		Broome et al., 1973
	S. alterniflora Medium		415	(471)	Stroud & Cooper, 1969
	S. alterniflora Medium	94	610		Marshall, 1970
	S. alterniflora Medium		355		Broome et al., 1973
	S. alterniflora Short		223	(280)	Stroud & Cooper, 1969
	S. alterniflora Short	68	370		Marshall, 1970
	S. alterniflora Short		241		Broome et al., 1973
	S. alterniflora	63.8	545	(650)	Williams & Murdoch, 1969
	Tall	140			"
	Medium	80			"
	Short	43			"
	Spartina patens			(1296)	Waits, 1967

TABLE 1. CONTINUED

	Juncus roemerianus			1000 (1000)	Williams & Murdoch, 1966
	Juncus roemerianus			(560)	Foster, 1968
	J. roemerianus			786 (1360)	Waits, 1967
	J. roemerianus			340 (850)	Williams & Murdoch, 1969
	J. roemerianus			654 (1215)	Stroud & Cooper, 1969
South Carolina	*Typha latifolia*			684	Boyd, 1970
	Typha latifolia			530-1132	Boyd, 1971
Southeastern US	*Typha latifolia*/*Typha angustifolia*			428-2252	Boyd & Hess, 1970
Georgia	*Spartina alterniflora*			900 (973)	Smalley, 1959
	S. alterniflora			(2000)	Schelske & Odum, 1961
	S. alterniflora			2248 (1608)	Teal, 1962**
	S. alterniflora	Tall		1685	Reimold et al., 1973b
	S. alterniflora	Tall		1333	Gallagher, 1973
	S. alterniflora	Tall		1350	Reimold et al., 1973a
	S. alterniflora	Tall	200-300	3018 (3990)	Odum & Fanning, 1973
	S. alterniflora	Medium		2018 (2362)	"

** GPP = 8452 g m^{-2}
Respiration = 6844 g (dry wt.) m^{-2} yr^{-1}

TABLE 1. CONTINUED

	S. alterniflora Medium		570-625	Reimold et al., 1993
	S. alterniflora Short		300	Gallagher, 1973
	S. alterniflora Short		385	Reimold et al., 1973
	Spartina cynosuroides	400-500	785 (910)	Odum & Fanning, 1973
	S. cynosuroides		762 (872)	"
	S. cynosuroides		515 (825)	"
	S. cynosuroides		1242 (2092)	"
	Juncus roemerianus		950	Reimold et al., 1973
	Distichlis spicata		345	"
Florida	*Juncus roemerianus*		232 (849)	Heald, 1969
Mississippi	*Juncus roemerianus*		(2000)	Eleuterius, 1972
	Juncus roemerianus		1697	de la Cruz, 1974b
	Juncus roemerianus		675 (390)	Gabriel & de la Cruz, 1974
	Spartina patens		1922	de la Cruz, 1974b
	Spartina cynosuroides		387 (475)	Gabriel & de la Cruz, 1974

TABLE 1. CONTINUED

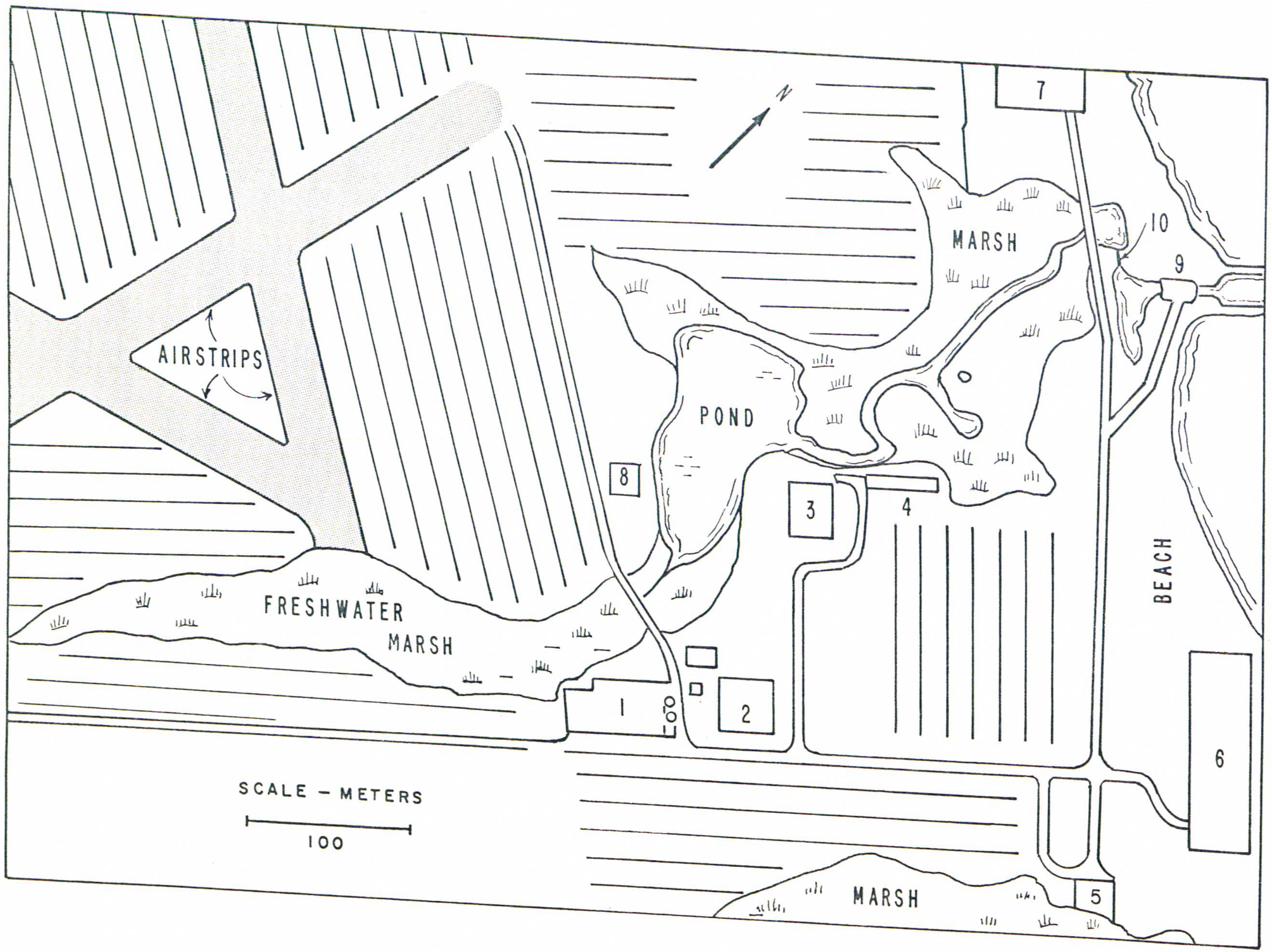
	S. cynosuroides	2190	de la Cruz, 1974b
	Distichlis spicata	45 (63)	Gabriel & de la Cruz, 1974
	D. spicata	1484	de la Cruz, 1974b
	Phragmites australis	2330	"
	S. alterniflora Tall	1964	"
	S. alterniflora Short	1089	"
Louisiana	*Spartina alterniflora*	(1150)	Kirby, 1971

Description of Study Site

The site of this study is a brackish marsh on the southern bank of the Choptank River along the eastern shore of the Chesapeake Bay. It is located at Horn Point (38^o 35' N latitude and 76^o 08' W longitude) on the outskirts of Cambridge, Maryland; the site of the new University of Maryland Center for Environmental and Estuarine Studies (UMCEES). In this area of the Choptank River, salinity ranges from 7 to 15 ppt annually and mean tidal range is 49 cm (NOAA Tide Tables, 1974). This marsh is comparatively small, approximately 5.7 hectares (14 acres) in size (Figure 1). It is bordered on the northwest and south by homes, by agricultural fields to the west and the Choptank River to the east. A tidal creek splits the brackish marsh on a north-south line forming a large shallow pond at the south-western end. The most inland portion of the marsh is a freshwater marsh dominated by *Hibiscus moscheutos* ssp. *moscheutos*.

A road divides the upper freshwater marsh from the brackish lower marsh and these marshes are connected by a 24" diameter culvert running under the road. Before emptying into the Choptank River, the creek flows through a two meter wide spillway with a concrete floor. This structure affects the tidal level of the marsh because the tide always flows out for a longer period of time than in and creates a "sill effect" (Nixon and Oviatt, 1973b). Occasionally, if the incoming tide is very small, the marsh may drain for 18-24

Figure 1. Map of Horn Point Marsh and surrounding UMCEES facilities. Key to numbers: (1) Barn Complex (2) Oyster Research Laboratory (3) House (4) Marsh Ecology Laboratory (5) Offices (6) UMCEES Administration Building (7) House (8) House (9) Boat House (10) Spillway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SCALE – METERS
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MARSH
5

12a

hours before the tide becomes high enough to reenter the marsh. A small pond has been formed at the beginning of the spillway by dredging. However, comparison of aerial photographs of the marsh in the 1930's shows little change in marsh zonation patterns, so in all probability the overall effect of the spillway installation in the 1950's and dredging had little impact on the Horn Point Marsh. The presence of tree stumps in the marsh indicates that this site is probably a relatively young marsh which is encroaching on surrounding fastland.

There are essentially eight major vegetational zones in the marsh which are mapped in Figure 1. Two of these are shrub zones - a Baccharis halimifolia zone around part of the perimeter of the marsh, and an Iva frutescens zone scattered throughout higher parts within the marsh. There is a large Spartina patens/Distichlis spicata zone in the comparatively higher areas, a very small Juncus roemerianus zone between the S. patens/D. spicata and Spartina alterniflora/Amaranthus cannabinus zones, a small Phragmites australis (communis) zone on part of the perimeter, a Typha angustifolia/Hibiscus moscheutos ssp. moscheutos zone next to the agricultural fields, a Hibiscus moscheutos ssp. moscheutos zone in the upper freshwater marsh and finally a Spartina alterniflora/Amaranthus cannabinus zone in low areas along the creek. The S. patens/D. spicata and S. alterniflora/A. cannabinus zones are split in two by the creek. A list of species which were collected and deposited at the University of Maryland Herbarium is given in Table II.

METHODS

Estimation of Aerial Net Community Production

Measurements of aerial community production were carried out by the difference method, in which differences in the average biomass of two or more consecutive samplings (harvests) of emergent vegetation plus the weight of the litter deposited during the time interval were determined. This harvest or clip quadrat method was employed because it is a convenient measurement of NCP and a measure of the energy available to the higher trophic levels and decomposers of the marsh (Odum, 1971).

Randomly selected quadrats were harvested in each plant association of the marsh monthly from May to September and bimonthly during the winter. These time intervals are short enough to detect the changes in productivity throughout the year but long enough to be practical from a logistics standpoint. Six plots of the *Spartina patens*/*Distichlis spicata* and *Spartina alterniflora*/*Amaranthus cannabinus* zones were harvested, three on either side of the creek, since later experimental work may involve splitting the marsh in two along the creek and using one side as a control. Three plots were harvested for all other zones. Sample size varies depending on the plant association being harvested. Circular 0.5 m^2 plots were used for the following zones:

TABLE II. SPECIES LIST FOR HORN POINT MARSH

Typha angustifolia/Hibiscus moscheutos Zone

- *Typha angustifolia*
- *Hibiscus moscheutos* ssp. *moscheutos*
- *Scirpus robustus*

Spartina patens/Distichlis spicata Zone

- *Spartina patens*
- *Distichlis spicata*
- *Scirpus robustus*
- *Fimbristylus spadicea*
- *Limonium carolinianum*
- *Sabatia stellaris*
- *Amaranthus cannabinus*
- *Iva frutescens*
- *Baccharis halimifolia*
- *Aster tenuifolius*
- *Cyperus strigosus*

Spartina alterniflora/Amaranthus cannabinus Zone

- *Spartina alterniflora*
- *Amaranthus cannabinus*
- *Atriplex patula* var. *hastata*
- *Aster tenuifolius*

Hibiscus moscheutos ssp. moscheutos Zone

- *Hibiscus moscheutos* ssp. *moscheutos*
- *Atriplex patula* var. *hastata*
- *Eleocharis halophila*
- *Leersia orysioides*

Juncus roemerianus Zone

- *Juncus roemerianus*

Phragmites australis Zone

- *Phragmites australis*

S. patens/D. spicata, S. alterniflora/A. cannabinus, Phragmites australis, and Typha/Hibiscus. Square 1.0 m^2 plots were used for the Hibiscus marsh since it has fewer stems per meter than most zones.

After harvesting, plants were refrigerated (not frozen) until separated into live and dead material. This material was then dried in a force air oven at 60^o C for 7 days. Therefore all biomass figures in this report are in terms of oven dry weight.

Caloric values of subsampled plant material for selected periods throughout the growing season were determined by using a Parr Automatic Adiabatic Bomb Calorimeter Model 1241 and corrected for heat of formation of nitric acid using sodium carbonate titration (ASTM Methods, 1968). All values are the average of two replicate samples.

Estimation of Aerial Net Primary Production

Aerial net primary production was estimated for the largest zones in the marsh, i.e. the freshwater Hibiscus zone and the brackish Spartina patens/Distichlis spicata zone. For this experiment, grazing exclosures were put out in each zone to prevent grazing by herbivores. In this way, estimates of NPP can be made since herbivore consumption is eliminated and the harvest method becomes more a measurement of NPP than NCP.

The exclosures were wooden frames covered with 1 mm mesh fiberglass screen. Since the screen reduced light intensity by 25-30% (measured with a weston light meter) and diminished wind movement over the plants, two different sets of controls were employed. The first controls were regular plots with no exclosure frame at all and were called control plots (CP). The second controls were plots with exclosure frames over them which were covered on top with screen but only half-way down every side (see Figure 2). This allowed herbivore consumption and increased air exchange but acted as a control for the reduced light intensity. These plots were called control cages (CC). The experimental plots called experimental cages (EC), were covered by exclosures which were completely covered with screen, and sprayed biweekly throughout the growing season with Malathion to prevent development of larval forms present in the soil and on vegetation. Three replicates were employed for each condition, making a total of nine plots for each of the two zones. The exclosures for the S. patens/D. spicata zone were 60 cm x 60 cm x 60 cm, thus covering 0.36 m^2 in surface area, and exclosures for the Hibiscus zone were 107.5 cm x 107.5 cm x 150 cm, thus covering 1.15 m^2 in surface area. The exclosures were put out in the S. patens/ D. spicata zone at the end of May, 1974, and in the Hibiscus zone at the beginning of June, 1974. Both zones were harvested July 21, 1974, which was the peak biomass period of the former zone.

Figure 2. Top Photograph of partially covered grazing exclosure in the *Spartina patens*/*Distichlis spicata* zone. This type of cage acted as a control for light and, like all the other cages, is made of wood and fiberglass screen of 1 mm mesh size.

Bottom Photograph of early transplant experiment in which cubes of the *Spartina patens*/*Distichlis spicata* root and rhizome mat were placed in trenches filled with creek sediment. These cubes failed to survive due to the anaerobic substrate.

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Estimation of Subterranean Production for *Spartina patens*

Estimates of subterranean production are difficult to determine for *Spartina* spp. and *Distichlis spicata* which typically produce an extensive rhizomatous mat in which it is impossible to distinguish past growth from present. Therefore one cannot simply determine the shoot:root ratio and estimate total production from the measured aerial production. This is why an experimental approach involving transplanting of *S. patens*/*D. spicata* rhizomes was used. Techniques for transplanting marsh plants have been used previously (Stalter and Batson, 1969; Woodhouse, Seneca, and Broome, 1972 and 1974; Broome, Woodhouse, and Seneca, 1973). Known weights of rhizome have been transplanted into natural substrates *in situ* and recovered after the sixth, ninth, and twelfth months to monitor increases in biomass. The experiment ran from August 2, 1973 to August 2, 1974.

Preliminary experiments in which *S. patens* and *D. spicata* rhizome had been transplanted into creek sediment failed, apparently the sediment was too anaerobic (see Figure 2). However, transplants placed in autoclaved mat material from the *S. patens*/*D. spicata* zone became well established. The autoclaved substrate in which these transplants were embedded was placed in trenches which were lined with fiberglass screen to keep neighboring rhizomes from intruding.

Linear Regression Analysis of Height Versus Weight

For all the harvests from July 21, 1973 to July 21, 1974 the height of ten plants in each quadrat were measured in the field to the nearest centimeter. The shoot height for each plot then, consists of an average height for ten randomly selected stems. Using these data in conjunction with the estimates of NCP, a least squares regression line has been calculated for height versus dry weight for all major plant associations throughout the year. By covariance techniques, all the lines in each zone were compared to each other to test for equality of slopes and elevations (means).

Determination of the Surface Area of the Marsh

The surface area of the marsh was measured from a map which was traced from a color aerial transparency. The area was determined by using a Bowen & Co. #P-205 Planimeter. The average of three replicate readings was used as the final estimates.

RESULTS AND OBSERVATIONS

Standing Crop and Adjusted Production Values

Live standing crop estimates for 1973 were begun in March and peaks in the standing crops occurred in July for the *Spartina patens*/*Distichlis spicata* (634 g/m^2), *Phragmites australis* (804 g/m^2), and the *Typha angustifolia*/*Hibiscus moscheutos* (778 g/m^2) zones while the *Spartina alterniflora*/*Amaranthus cannabinus* (574 g/m^2) zone peaked in September and the *Hibiscus moscheutos* (588 g/m^2) zone peaked in August (see Tables III-XI). For the 1974 growing season, the peak standing crops occurred in the same months for all zones as in 1973 except in the *Spartina alterniflora*/*Amaranthus cannabinus* zone which peaked in July (777 g/m^2) instead of September (570 g/m^2).

Surprisingly, some *Spartina patens*, *Distichlis spicata*, and *Spartina alterniflora* plants remained vital all year-round. Despite freezing temperatures small green shoots persisted at the base of the previous summer's dead stems while all other zones died back completely. In the spring of 1974 new growth resumed in the *P. australis* and *Typha*/*Hibiscus* zones in early April but growth in the *Hibiscus moscheutos* zone did not resume until late April or early May. Standing crop estimates for the 1974 growing season were stopped after the peak month of the previous growing

TABLE III. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR ELEVEN STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND JULY 21, 1974 FOR <u>PHRAGMITES AUSTRALIS</u>

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73	0.00				-	
5/23/73	259	124.8	72.1		-	
6/24/73	387	19.2	11.1		-	
7/21/73	804	124.9	72.1	285.5	54.5	9.95
8/21/73	511	309.5	178.7	278.9	51.1	9.3
9/21/73	375	313.7	181.1	265.0	65.5	13.97
11/16/73	0.00			270.6	54.4	9.9
1/19/74	0.00				-	
4/6/74	2	0.58	0.33	8.4	1.97	0.44
5/31/74	532	84.6	48.97	199.9	43.9	8.0
7/21/74	979	112.4	64.9	291	50.3	9.2

TABLE IV. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR ELEVEN STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND JULY 21, 1974 FOR SPARTINA PATENS/DISTICHLIS SPICATA

	Live Biomass				Height		
Date	Mean	S.D.	S.E.		Mean	S.D.	S.E.
3/31/73	28	8.7	3.6			-	
5/23/73	298	64.3	26.3			-	
6/24/73	484	100.7	41.1			-	
7/21/73	635	100.3	40.9		48	6.96	0.90
8/21/73	589 ~~350~~	106.5 ~~77.5~~	43.5 ~~44.7~~	D.R.C.	56	11.7	1.5
9/21/73	391	141.3	57.7	6/7/78	47	16.1	2.1
11/16/73	272	75.7	30.9		46	14.7	1.9
1/19/74	95	42.0	17.2			-	
4/6/74	73	50.9	20.8		13	2.9	0.37
5/31/74	273	33.1	13.5		33	5.2	0.68
7/21/74	622	181.9	105.0		42	8.3	1.1

TABLE V. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR ELEVEN STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND JULY 21, 1974 FOR <u>HIBISCUS</u> <u>MOSCHEUTOS</u>

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73		-			-	
5/23/73	274	150.1	86.7		-	
6/24/73	359	184.2	106.3		-	
7/21/73	402	63.3	36.6	112	15.1	2.8
8/21/73	~~589~~ 350	~~106.5~~ 77.5	~~43.5~~ 44.7 D.R.C. 6/7/78	112	20.8	3.8
9/21/73	485	146.9	84.8	134	15.5	2.8
11/16/73	0.00			144	20.6	3.8
1/19/74	0.00			0.00		
4/6/74	0.00			0.00		
5/31/74	118	7.5	4.3	69	13.9	2.5
7/21/74	~~445~~ 576	~~213.0~~ 58.95	~~122.99~~ 34.0 D.R.C. 6/7/78	122	27.8	5.1

TABLE VI. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR TWELVE STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND SEPTEMBER 21, 1974 FOR SPARTINA ALTERNIFLORA

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73	4	3.9	1.6		-	
5/23/73		-			-	
6/24/73	194	197.9	80.8		-	
7/21/73	308	176.2	71.9	81	19.5	2.5
8/21/73	346	77.5	31.7	106	22.6	2.9
9/21/73	468	106.96	43.7	119	21.0	2.7
11/16/73	369	169.5	69.2	107	21.7	2.8
1/19/74	3	2.7	1.1		-	
4/6/74	17	17.8	7.3	17	5.7	0.74
5/31/74	177	51.9	21.1	66	12.5	1.6
7/21/74	475	152.3	62.2	97	18.6	2.4
9/21/74	423	166.8	68.1	115	20.2	2.6

TABLE VII. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR TWELVE STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND SEPTEMBER 21, 1974 FOR AMARANTHUS CANNABINUS

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73	0.00				-	
5/23/73	0.00				-	
6/24/73	40	36.1	14.8		-	
7/21/73	168	125.98	51.4	72	17.5	2.4
8/21/73	113	73.1	29.8	90	15.4	2.1
9/21/73	107	76.2	31.1	89	14.9	2.2
11/16/73	0.00				0.00	
1/19/74	0.00				0.00	
4/6/74	0.00				0.00	
5/31/74	11	17.5	7.2	29	6.7	0.86
7/21/74	210	96.6	39.5	82	18.7	2.4
9/21/74	59	35.7	14.6	83	17.4	2.5

TABLE VIII. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR THE ENTIRE ZONE FOR TWELVE STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND SEPTEMBER 21, 1974 FOR *SPARTINA ALTERNIFLORA/AMARANTHUS CANNABINUS*

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73	4	3.9	1.6		-	
5/23/73		-			-	
6/24/73	259	155.7	63.6		-	
7/21/73	556	152.7	62.3		-	
8/21/73	524	93.4	38.1		-	
9/21/73	575	89.95	36.7		-	
11/16/73	369	169.5	69.2		-	
1/19/74	3	2.7	1.1		-	
4/6/74	17	17.8	7.3		-	
5/32/74	213	30.5	12.4		-	
7/21/74	777	293.8	119.9		-	
9/21/74	571	206.2	84.2		-	

TABLE IX. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR ELEVEN STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND JULY 21, 1974 FOR *TYPHA ANGUSTIFOLIA*

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73		-			-	
5/23/73		-			-	
6/24/73	443	251.8	145.4		-	
7/21/73	546	147.96	85.4	187	18.7	3.5
8/21/73	665	54.9	31.7	192	17.0	3.1
9/21/73	481	168.1	97.0	178	36.2	6.6
11/16/73	0.00			131	33.1	6.0
1/19/74	0.00			0.00		
4/6/74	4	3.5	2.0	23	5.6	1.3
5/31/74	611	84.7	48.9	165	16.1	2.9
7/21/74	1304	833.9	481.4	184	20.7	3.8

TABLE X. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR ELEVEN STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND JULY 21, 1974 FOR *HIBISCUS MOSCHEUTOS* - *TYPHA/HIBISCUS*

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73	0.00				-	
5/23/73		-			-	
6/24/73	111	96.6	55.7		-	
7/21/73	232	207.4	119.7	103	22.5	4.7
8/21/73	10	17.0	9.8	114	8.1	4.7
9/21/73	71	50.8	29.3	112	25.6	5.6
11/16/73	0.00			147	33.6	8.4
1/19/74	0.00			0.00		
4/6/74	0.00			0.00		
5/31/74	43	47.4	27.4	66	13.5	3.0
7/21/74	137	118.5	68.4	136	14.0	3.2

TABLE XI. THE AVERAGE LIVE BIOMASS (G DRY WT./M^2) AND AVERAGE HEIGHT (CM) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR THE ENTIRE ZONE FOR ELEVEN STANDING CROP ESTIMATES BETWEEN MARCH 31, 1973 AND JULY 21, 1974 FOR <u>TYPHA ANGUSTIFOLIA/HIBISCUS MOSCHEUTOS</u>

	Live Biomass			Height		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.
3/31/73	0.00				-	
5/23/73		-			-	
6/24/73	554	161.1	93.0		-	
7/21/73	778	147.1	84.9		-	
8/21/73	682	44.5	25.7		-	
9/21/73	553	120.3	69.5		-	
11/16/73	0.00				-	
1/19/74	0.00				-	
4/6/74	4	3.5	2.0		-	
5/31/74	655	52.6	30.3		-	
7/21/74	1442	927.4	535.4		-	

season had been reached except in the *Hibiscus moscheutos* zone. The sampling was terminated in July along with the other zones. In every zone the peak had not been reached before the time of the previous year's peak but obviously there is no way of telling if the zones peaked later than the previous year. An additional harvest was taken in the *S. alterniflora*/*A. cannabinus* zone on September 21, 1974 since it peaked later than the other zones in 1973.

All standing crop estimates have been adjusted to a monthly basis in Tables XII through XXIV and *Spartina alterniflora*, *Amaranthus cannabinus*, *Typha angustifolia*, and *Hibiscus moscheutos* are to be treated individually by species, not clumped together as a zone for Tables XII - XVIII. In this way, estimates of standing crop for any given time in the growing season can be easily made for all species. These monthly adjusted standing crop values peak at least one month later than the unadjusted standing crop values in every species except *T. angustifolia* which peaks at the same time (see Tables XII - XVIII). In every species except for *A. cannabinus* in 1974, the adjusted peak values are lower than the unadjusted peak values. This change in the month and in the amount of the peak value is an artifact of the adjustment. These anomalies are more than compensated for by the flexibility gained by adjustment.

An advantage of adjusting the standing crop estimates to a monthly basis is that monthly net biomass estimates can be calculated by determining the difference between two

TABLE XII. ADJUSTED STANDING CROP, MONTHLY NET BIOMASS, AND DAILY RATE FOR *PHRAGMITES AUSTRALIS* (G DRY WT./M^2)

Date	Standing Crop	Monthly Net Biomass	Daily Rate
4/1/73	4		
		146	+4.86
5/1/73	150		
		146	+4.71
6/1/73	296		
		196	+6.53
7/1/73	492		
		204	+6.58
8/1/73	696		
		-234	-7.55
9/1/73	462		
		-154	-5.13
10/1/73	308		
		-208	-6.71
11/1/73	100		
		-100	-3.33
12/1/73	0		
		0	0.00
1/1/74	0		
		0	0.00
2/1/74	0		
		0	0.00
3/1/74	0		
		2	+0.0
4/1/74	2		
		244	+8.13
5/1/74	246		
		294	+9.48
6/1/74	540		
		264	+8.80
7/1/74	804		

TABLE XIII. ADJUSTED STANDING CROP, MONTHLY NET BIOMASS, AND DAILY RATE FOR *SPARTINA PATENS*/*DISTICHLIS SPICATA* (G DRY WT./M^2)

Date	Standing Crop	Monthly Net Biomass	Daily Rate
4/1/73	32		
		152	+5.06
5/1/73	184		
		166	+5.35
6/1/73	350		
		174	+5.80
7/1/73	524		
		93	+3.00
8/1/73	617		
		-97	-3.13
9/1/73	520		
		-152	-5.06
10/1/73	368		
		-65	-2.10
11/1/73	303		
		-73	-2.43
12/1/73	230		
		-87	-2.81
1/1/74	143		
		-52	-1.68
2/1/74	91		
		-8	-0.29
3/1/74	83		
		-9	-0.30
4/1/74	74		
		90	+3.00
5/1/74	164		
		112	+3.61
6/1/74	276		
		130	+4.33
7/1/74	406		

TABLE XIV. ADJUSTED STANDING CROP, MONTHLY NET BIOMASS, AND DAILY RATE FOR *HIBISCUS MOSCHEUTOS* (G DRY WT./M^2)

Date	Standing Crop	Monthly Net Biomass	Daily Rate
4/1/73	Not Sampled		
5/1/73	Not Sampled		
6/1/73	298		
		72	+2.40
7/1/73	370		
		14	+0.45
8/1/73	384		
		13	+0.42
9/1/73	397		
		44	+1.46
10/1/73	441		
		-126	-4.06
11/1/73	315		
		-119	-3.96
12/1/73	196		
		-126	-4.06
1/1/74	70		
		-70	-2.26
2/1/74	0		
		0	0.00
3/1/74	0		
		0	0.00
4/1/74	0		
		54	+1.80
5/1/74	54		
		72	+2.32
6/1/74	126		
		270	+9.00
7/1/74	396		

TABLE XV. ADJUSTED STANDING CROP, MONTHLY NET BIOMASS, AND DAILY RATE FOR *SPARTINA ALTERNIFLORA* (G DRY WT./M^2)

Date	Standing Crop	Monthly Net Biomass	Daily Rate
4/1/73	6		
		67	+2.23
5/1/73	73		
		69	+2.23
6/1/73	142		
		79	+2.63
7/1/73	221		
		100	+3.23
8/1/73	321		
		69	+2.23
9/1/73	390		
		59	+1.97
10/1/73	449		
		-55	-1.77
11/1/73	394		
		-113	-3.76
12/1/73	281		
		-177	-5.71
1/1/74	104		
		-100	-3.23
2/1/74	4		
		6	+0.21
3/1/74	10		
		6	+0.19
4/1/74	16		
		73	+2.43
5/1/74	89		
		93	+3.00
6/1/74	182		
		175	+5.83
7/1/74	357		
		109	+3.52
8/1/74	466		
		-26	-0.84
9/1/74	440		

TABLE XVI. ADJUSTED STANDING CROP, MONTHLY NET BIOMASS, AND DAILY RATE FOR <u>AMARANTHUS</u> <u>CANNABINUS</u> (G DRY WT./M^2)

Date	Standing Crop	Monthly Net Biomass	Daily Rate
4/1/73	0		
		0	0.00
5/1/73	0		
		12	+0.39
6/1/73	12		
		60	+2.00
7/1/73	72		
		76	+2.45
8/1/73	148		
		-38	-1.23
9/1/73	110		
		-22	-0.73
10/1/73	88		
		-60	-1.94
11/1/73	28		
		-28	-0.93
12/1/73	0		
		0	0.00
1/1/74	0		
		0	0.00
2/1/74	0		
		0	0.00
3/1/74	0		
		0	0.00
4/1/74	0		
		5	+0.17
5/1/74	5		
		9	+0.29
6/1/74	14		
		116	+3.86
7/1/74	130		
		106	+3.42
8/1/74	236		
		72	+2.32
9/1/74	308		

TABLE XVII. ADJUSTED STANDING CROP, MONTHLY NET BIOMASS, AND DAILY RATE FOR <u>TYPHA ANGUSTIFOLIA</u> (G DRY WT./M^2)

Date	Standing Crop	Monthly Net Biomass	Daily Rate
4/1/73	5		
		157	+5.23
5/1/73	162		
		162	+5.23
6/1/73	324		
		146	+4.86
7/1/73	470		
		118	+3.81
8/1/73	588		
		-16	-0.52
9/1/73	572		
		-238	-7.93
10/1/73	334		
		-224	-7.23
11/1/73	110		
		-110	-3.66
12/1/73	0		
		0	0.00
1/1/74	0		
		0	0.00
2/1/74	0		
		2	+0.07
3/1/74	2		
		2	+0.07
4/1/74	4		
		282	+9.40
5/1/74	286		
		340	+10.97
6/1/74	626		
		416	+13.86
7/1/74	1042		

TABLE XVIII. ADJUSTED STANDING CROP, MONTHLY NET BIOMASS, AND DAILY RATE FOR *HIBISCUS MOSCHEUTOS* FROM THE *TYPHA*/*HIBISCUS* ZONE (G DRY WT./M^2)

Date	Standing Crop	Monthly Net Biomass	Daily Rate
4/1/73	1		
		39	+1.3
5/1/73	40		
		41	+1.32
6/1/73	81		
		51	+1.7
7/1/73	132		
		24	+0.77
8/1/73	156		
		-124	-4.00
9/1/73	32		
		26	+0.86
10/1/73	58		
		-38	-1.23
11/1/73	20		
		-20	-0.67
12/1/73	0		
		0	0.00
1/1/74	0		
		0	0.00
2/1/74	0		
		0	0.00
3/1/74	0		
		0	0.00
4/1/74	0		
		20	+0.67
5/1/74	20		
		25	+0.81
6/1/74	45		
		62	+2.06
7/1/74	107		

consecutive adjusted standing crop estimates. This gives a month by month production estimate throughout the entire year and a tabulation of the rates of production throughout the growing season as well (see Tables XII - XVIII). In three of the zones the net biomass estimates also do not peak at the same time as the unadjusted estimates. The *Spartina patens*/*Distichlis spicata* zone peaked in June as opposed to July, the *Spartina alterniflora* peaked in July instead of September while *Amaranthus cannabinus* peaked at the same time, and *Hibiscus moscheutos* from the *Typha*/*Hibiscus* zone peaked in June as opposed to July yet *Typha angustifolia* peaked at the same time.

Another advantage of adjusting the NCP values to a monthly basis is that daily rates of production can also be calculated from the estimated monthly net biomass. Obviously the yearly patterns of production will be the same for these daily rates as it is for the monthly net biomass (see Tables XII - XVIII), and these data can be used to estimate daily production for any time throughout the year.

The largest producer in terms of adjusted standing crop (1042 g/m^2). monthly net biomass (416 g/m^2), and daily rate (13.86 g/m^2) is *Typha angustifolia* from the *Typha*/*Hibiscus* zone and second largest in all three aspects is *Phragmites australis*. The *Spartina patens*/*Distichlis spicata* zone is the third largest producer in adjusted standing crop but fifth in monthly net biomass and daily rate. *Hibiscus moscheutos* ranks third in monthly net biomass and daily rate even though it ranks fifth in adjusted standing crop. *Spartina alterniflora*, *Amaranthus cannabinus*, and *Hibiscus* from the *Typha*/*Hibiscus* zone rank fourth, sixth, and seventh in all three aspects of production, respectively.

To detect significant yearly differences in rates of production, an analysis of variance (ANOVA) was conducted using the daily rates of production for April through August in 1973 versus 1974 and the result is presented in Table XIX. The variation in the species *Spartina alterniflora*, *Amaranthus cannabinus*, and *Hibiscus moscheutos* from the *Typha*/*Hibiscus* zone was found to be nonsignificant at the 1% level but significant differences at the 1% level were found in the species *Phragmites australis* and *Typha angustifolia*. The *Spartina patens*/*Distichlis spicata* zone had significant differences at the 5% level but not the 1% level.

Surface Area and Areally Weighted Production Estimates

The total surface area of the marsh is approximately 56,700 m^2 (14 acres). Of this, close to 14,000 m^2 (25%) is open water and 42,700 m^2 (75%) is covered with emergent marsh plants. The largest portion of the latter area is occupied by the *Spartina patens*/*Distichlis spicata* zone (29%) with the *Hibiscus moscheutos* zone being the second largest in size (27%). The surface area figures presented in Table XX were used to estimate the NCP for each zone of the marsh by areally weighting all adjusted production estimates.

Despite ranking third in adjusted standing crop the *Spartina patens*/*Distichlis spicata* zone is the greatest

TABLE XIX. ANALYSIS OF VARIANCE FOR DAILY RATES OF PRODUCTION IN THE DOMINANT SPECIES AT HORN POINT MARSH IN 1973 VERSUS 1974

Species	Source of Variation	df	SS	MS	F	P less than
S. patens/	Within Cells	4	1.165	.291	15.899	.016
D. spicata	Years	1	4.629	4.629		
Phragmites	Within Cells	4	2.953	.738	24.001	.008
australis	Years	1	17.716	17.716		
Typha/Hibiscus -	Within Cells	4	10.327	2.582	23.083	.009
Typha	Years	1	59.598	59.598		
Typha/Hibiscus -	Within Cells	4	1.273	.318	.319	.603
Hibiscus	Years	1	.101	.101		
Spartina	Within Cells	8	23.893	2.987	.065	.806
alterniflora	Years	1	.193	.193		
Amaranthus	Within Cells	8	21.254	2.657	1.746	.223
cannabinus	Years	1	4.638	4.638		

producer in the marsh in terms of weighted, adjusted standing crop. It has the largest peak value of 7.61 metric tons and is also the largest producer throughout the entire year with the exception of Hibiscus moscheutos in October, 1973 (see Table XXI). The lowest standing crop estimate for this zone is 5.8% of the peak value. The second most important producer is the Hibiscus moscheutos zone with a peak value of 5.07 metric tons and next is the Spartina alterniflora/ Amaranthus cannabinus zone with 3.22 metric tons. The Phragmites australis and Typha/Hibiscus zones produced the least with Phragmites having a slightly higher peak but producing less overall. With all zones combined the peak for total marsh production occurred in August, 1973 with 16.14 metric tons and in July, 1974 with 14.2 metric tons. The lowest reading came on April 1, 1973 with 0.439 metric tons produced.

In order to determine what portion of the total marsh production is attributable to each species, the percent of total marsh production was calculated for each zone for all 16 months (see Table XXII). As expected, the Spartina patens/ Distichlis spicata zone generated the largest percentage of live production in the winter (98% of total) and a peak at the height of the growing season in 1973 of 47% and in 1974 of 35%. All other zones follow the same order as the previously mentioned standing crop estimates.

The weighted monthly net biomass estimates do not follow all the same trends of the weighted adjusted standing crop estimates (see Table XXIII). Again, the most important

TABLE XX. SURFACE AREA OF THE MARSH (M^2) AND PERCENT OF TOTAL AND TERRESTRIAL AREA COVERED BY EACH SPECIES

Species	Area	Percent Total	Percent Terrestrial
T. angustifolia/H. moscheutos	866	1.53	2.03
Kosteletzkya virginica	214	0.39	0.50
Phragmites australis	947	1.67	2.22
Iva frutescens	5,746	10.14	13.45
Water	13,969	24.64	-
S. alterniflora/A. cannabinus	5,999	10.58	14.04
S. alterniflora/Iva frutescens	3,472	6.13	8.13
S. patens/D. spicata	12,334	21.76	28.87
Juncus roemerianus	38	0.07	0.09
S. patens/T. angustifolia	524	0.93	1.23
Hibiscus moscheutos	11,490	20.27	26.89
Baccharis halimifolia	1,089	1.92	2.55
Total	56,690		
Total Terrestrial	42,721	75.36	

TABLE XXI. AREALLY WEIGHTED AND ADJUSTED STANDING CROP ESTIMATES (G DRY WT.) FOR THE SPARTINA ALTERNIFLORA/AMARANTHUS CANNABINUS, SPARTINA PATENS/DISTICHLIS SPICATA, PHRAGMITES AUSTRALIS, HIBISCUS MOSCHEUTOS, AND TYPHA/HIBISCUS ZONES AT HORN POINT MARSH

Date	*S. alterniflora/ A. cannabinus*	*S. patens/ D. spicata*	*Phragmites australis*	*Hibiscus moscheutos*	*Typha/Hibiscus*
4/1/73	35,994	394,688	3,788	not sampled	5,196
5/1/73	437,927	2,269,456	142,050	not sampled	174,932
6/1/73	923,846	4,316,900	280,312	3,424,020	350,730
7/1/73	1,757,707	6,463,016	465,924	4,251,300	521,332
8/1/73	2,813,531	7,610,078	659,112	4,412,160	644,304
9/1/73	2,999,500	6,413,680	437,514	4,561,530	523,064
10/1/73	3,221,463	4,538,912	291,676	5,067,090	339,472
11/1/73	2,531,578	3,737,202	94,700	3,619,350	112,580
12/1/73	1,685,719	2,836,820	0	2,252,040	0
1/1/74	623,896	1,763,762	0	804,300	0
2/1/74	23,996	1,122,394	0	0	0
3/1/74	59,990	1,023,722	0	0	1,732
4/1/74	95,984	912,716	1,894	0	3,464
5/1/74	563,906	2,022,776	232,962	620,460	264,996
6/1/74	1,175,804	3,404,184	511,380	1,447,740	581,086
7/1/74	2,921,513	5,007,604	761,388	4,550,040	995,034
8/1/74	4,211,298	not sampled	not sampled	not sampled	not sampled
9/1/74	4,487,252	not sampled	not sampled	not sampled	not sampled

producer in 1973 was the Spartina patens/Distichlis spicata zone with a peak value of 2.15 metric tons in June but in June, 1974 the Hibiscus moscheutos zone produced the most with 3.10 metric tons. Overall, however, the general order of importance remains the same, S. patens/D. spicata and H. moscheutos are the most important and the others descend in the same order as before.

Table XXIV presents the increase in total monthly net biomass and the percent attributable to each zone. Table XXV presents the decrease in total monthly net biomass and the percent attibutable to each zone. When all zones are combined for the increase in live biomass, the total marsh production hits its 1973 peak in June with 4.2 metric tons gained and it peaks again in June, 1974 with 7.1 metric tons gained. In 1973 the Spartina patens/Distichlis spicata zone is the most responsible for the production estimate (51%) and in 1974 the Hibiscus moscheutos zone is most responsible (43.6%). When all 16 months are summed the total gain is 28.7 metric tons.

The greatest decrease in live biomass occurs in December of 1973 with 3.58 metric tons lost for the marsh as a whole (see Table XXV). The largest loss occurred in the Hibiscus moscheutos zone (40%). The zone of highest production, Spartina patens/Distichlis spicata, loses the most biomass in the two months after the peak (68 and 80%, respectively) but then slows down to account for roughly 25 - 30% of the losses. The Hibiscus moscheutos zone consistently accounts for at least 40% of the losses throughout the winter and the

TABLE XXII. TOTAL AREALLY WEIGHTED AND ADJUSTED STANDING CROP FOR EACH MONTH FROM APRIL 1, 1973 TO JULY 1, 1974 AND PERCENT OF TOTAL AREALLY WEIGHTED AND ADJUSTED STANDING CROP ATTRIBUTED TO EACH OF THE FIVE MAJOR ZONES

Date	Total Marsh Production	Percent of Total Marsh Production				
		S. alterniflora/ A. cannabinus	S. patens/ D. spicata	Phragmites australis	Hibiscus moscheutos	Typha/ Hibiscus
4/1/73	439,666	8.19	39.77	0.86	not sampled	1.18
5/1/73	3,024,365	14.48	75.04	4.70	not sampled	5.78
6/1/73	9,295,808	9.94	46.44	3.02	36.83	3.77
7/1/73	13,459,279	13.06	48.02	3.46	31.59	3.87
8/1/73	16,139,185	17.43	47.15	4.08	27.34	3.99
9/1/73	14,935,288	20.08	42.94	2.93	30.54	3.50
10/1/73	13,458,613	23.94	33.72	2.17	37.65	2.52
11/1/73	10,095,410	25.08	37.02	0.94	35.85	1.12
12/1/73	6,774,579	24.88	41.87	0.00	33.24	0.00
1/1/74	3,191,958	19.55	55.26	0.00	25.20	0.00
2/1/74	1,146,390	2.09	97.91	0.00	00.00	0.00
3/1/74	1,085,444	5.53	94.31	0.00	00.00	0.16
4/1/74	1,014,058	9.47	90.01	0.19	00.00	0.34
5/1/74	3,705,100	15.22	54.59	6.29	16.75	7.15
6/1/74	7,120,194	16.51	47.81	7.18	20.33	8.16
7/1/74	14,235,579	20.52	35.18	5.35	31.96	6.99

TABLE XXIII. AREALLY WEIGHTED AND ADJUSTED MONTHLY NET BIOMASS ESTIMATES (G DRY WT.) FOR APRIL, 1973 TO AUGUST, 1974 FOR THE *SPARTINA ALTERNIFLORA/AMARANTHUS CANNABINUS*, *SPARTINA PATENS/DISTICHLIS SPICATA*, *PHRAGMITES AUSTRALIS*, *HIBISCUS MOSCHEUTOS*, AND *TYPHA/HIBISCUS* ZONES AT HORN POINT MARSH

Date	*S. alterniflora/ A. cannabinus*	*S. patens/ D. spicata*	*Phragmites australis*	*Hibiscus moscheutos*	*Typha/ Hibiscus*
4/73	401,933	1,874,768	138,262	not sampled	169,736
5/73	485,919	2,047,444	138,262	not sampled	175,798
6/73	833,861	2,146,116	185,612	827,280	170,602
7/73	1,055,824	1,147,062	193,188	160,860	122,972
8/73	413,931-227,962	-1,196,398	-221,598	149,370	-121,240
9/73	353,941-131,978	-1,874,768	-145,838	505,560	-183,592
10/73	-689,885	-801,710	-196,976	-1,447,740	-226,892
11/73	-845,859	-900,382	-94,700	-1,367,310	-112,580
12/73	-1,061,823	-1,073,058	0	-1,447,740	0
1/74	-599,900	-641,368	0	-804,300	866-0
2/74	35,994-0	-98,672	0	0	866-0
3/74	35,994-0	-111,006	0	0	1,732-0
4/74	467,922	1,110,060	231,068	620,460	261,532
5/74	611,898	1,381,408	278,418	827,280	316,090
6/74	1,745,709	1,603,420	250,008	3,102,300	413,948
7/74	1,289,785	not sampled	not sampled	not sampled	not sampled
8/74	-155,974+431,928	not sampled	not sampled	not sampled	not sampled

Spartina alterniflora/Amaranthus cannabinus zone starts out low but then accounts for about 25 - 30% of the losses in mid winter. The Phragmites australis and Typha/Hibiscus zones both account for usually less than 10% of the losses. The total loss for the 16 month period is 16.78 metric tons.

Net Primary Productivity

The grazing exclosure experiments for estimating net primary productivity of the Spartina patens/Distichlis spicata and Hibiscus moscheutos zones demonstrated that there is no significant difference in the mean standing crop between the controls and the experimental plots for either zone ($P < .451$ and $P < .241$, respectively - see Tables XXVI and XXVII). Interestingly, in the S. patens/D. spicata zone the experimental units had the lowest standing crop (520 ± 47 S. E. g/m^2 for the control cage or 19.6% less than the control plot (CP) and 501 ± 25 g/m^2 for the experimental cage or 24% less than the CP), the exact opposite of what was expected. The control yielded 622 ± 105 g/m^2. In the H. moscheutos zone the plants in the experimental cage (630 ± 65 g/m^2) were taller, more robust, and generally much healthier looking than the controls. The leaves were also much larger and considerably greener (see Figure 3). The control cages yielded 658 ± 54 g/m^2 and the control plots yielded 444 ± 123 g/m^2. The entire zone flowered one week after the completion of this experiment and it is therefore safe to assume that these NPP estimates are near the peak biomass of the 1974 growing season for H. moscheutos since

TABLE XXIV. TOTAL INCREASE IN AREALLY WEIGHTED AND ADJUSTED MONTHLY NET BIOMASS (G DRY WT.) FOR EACH MONTH FROM APRIL, 1973 TO AUGUST, 1974 AND PERCENT OF INCREASE ATTRIBUTED TO EACH OF THE FIVE MAJOR ZONES

Date	Increase in Total Monthly Net Biomass	Percent of Increase				
		S. alterniflora/ *A. cannabinus*	*S. patens*/ *D. spicata*	*Phragmites australis*	*Hibiscus moscheutos*	*Typha*/ *Hibiscus*
4/73	2,584,699	15.55	72.53	5.35	not sampled	6.57
5/73	2,847,423	17.07	71.91	4.86	not sampled	6.17
6/73	4,163,471	20.03	51.55	4.46	19.87	4.10
7/73	2,679,906	39.40	42.80	7.21	6.00	4.59
8/73	563,301	73.48	00.00	0.00	26.52	0.00
9/73	859,501	41.20	00.00	0.00	58.80	0.00
10/73	0	-	-	-	-	-
11/73	0	-	-	-	-	-
12/73	0	-	-	-	-	-
1/74	866	00.00	00.00	0.00	00.00	100.00
2/74	36,860	97.65	00.00	0.00	00.00	2.35
3/74	37,726	95.40	00.00	0.00	00.00	4.60
4/74	2,691,042	17.39	41.25	8.59	23.06	9.72
5/74	3,415,094	17.92	40.45	8.15	24.22	9.26
6/74	7,115,385	24.53	22.53	3.51	43.60	5.82
7/74	1,289,785	100.00	not sampled	not sampled	not sampled	not sampled
8/74	431,928	100.00	not sampled	not sampled	not sampled	not sampled

TABLE XXV. TOTAL DECREASE IN AREALLY WEIGHTED AND ADJUSTED MONTHLY NET BIOMASS (G DRY WT.) FOR EACH MONTH FROM APRIL, 1973 TO AUGUST, 1974 AND PERCENT OF DECREASE ATTRIBUTED TO EACH OF THE FIVE MAJOR ZONES

Date	Decrease in Total Monthly Net Biomass	Percent of Decrease				
		S. alterniflora/ *A. cannabinus*	*S. patens*/ *D. spicata*	*Phragmites australis*	*Hibiscus moscheutos*	*Typha*/ *Hibiscus*
4/73	0	-	-	-	-	-
5/73	0	-	-	-	-	-
6/73	0	-	-	-	-	-
7/73	0	-	-	-	-	-
8/73	-1,767,198	12.90	67.70	12.54	00.00	6.86
9/73	-2,336,176	5.65	80.25	6.24	00.00	7.86
10/73	-3,363,203	20.51	23.84	5.86	43.05	6.75
11/73	-3,320,831	25.47	27.11	2.85	41.17	3.39
12/73	-3,582,621	29.64	29.95	0.00	40.41	0.00
1/74	-2,045,568	29.33	31.35	0.00	39.32	0.00
2/74	-98,672	00.00	100.00	0.00	00.00	0.00
3/74	-111,006	00.00	100.00	0.00	00.00	0.00
4/74	0	-	-	-	-	-
5/74	0	-	-	-	-	-
6/74	0	-	-	-	-	-
7/74	0	-	not sampled	not sampled	not sampled	not sampled
8/74	-155,974	100.00	not sampled	not sampled	not sampled	not sampled

the flowers are terminal and further growth of branches would be terminated. Unlike the H. moscheutos plants, differences in stature and health were not so noticeable between the plots of the S. patens/D. spicata plants.

Linear contrasts of the three means in each zone showed that the control for light was nonsignificantly different from the completely enclosed cages ($P < .853$ and $P < .828$, respectively). The control plots (no cage) were also shown to be nonsignificantly different from the other two types of plots, but with a much lower probability ($P < .230$ and $P < .107$, respectively). The Hibiscus control plot is almost significantly different at the 10% level because the control cage yielded 32.5% more biomass and the experimental cage yielded 29.5% more.

Efficiency of Production

In 1974 the efficiency rate for conversion of solar radiation to plant production at Horn Point Marsh ranged from 0.11 to 1.12%. For comparison, the calculations in Table XXVIII are presented in the same format as for Bissel Cove (Nixon and Oviatt, 1973b). In some species our values are similar to Bissel Cove but in most our efficiency rates are higher. For example, our rate of 0.53% for the Spartina alterniflora/Amaranthus cannabinus zone is about equal to the rate of 0.51% for Tall S. alterniflora at Bissel Cove Marsh. However, our efficiency rate for the Spartina patens/Distichlis spicata mixture is nearly 50% greater than the

Figure 3. _Top_ Photograph of _Hibiscus_ _moscheutos_ plants in the fresh marsh with protected plants from the totally enclosed cage on the right and unprotected control plants on the left. Note the difference in height, color, size of leaves, amount of predation.

Bottom Photograph of a _Spartina_ _patens_/_Distichlis_ _spicata_ transplant cube after 12 months. Originally the cube was 1" square and 2" long, the Whirlpak bag is 9" long and 4" wide.

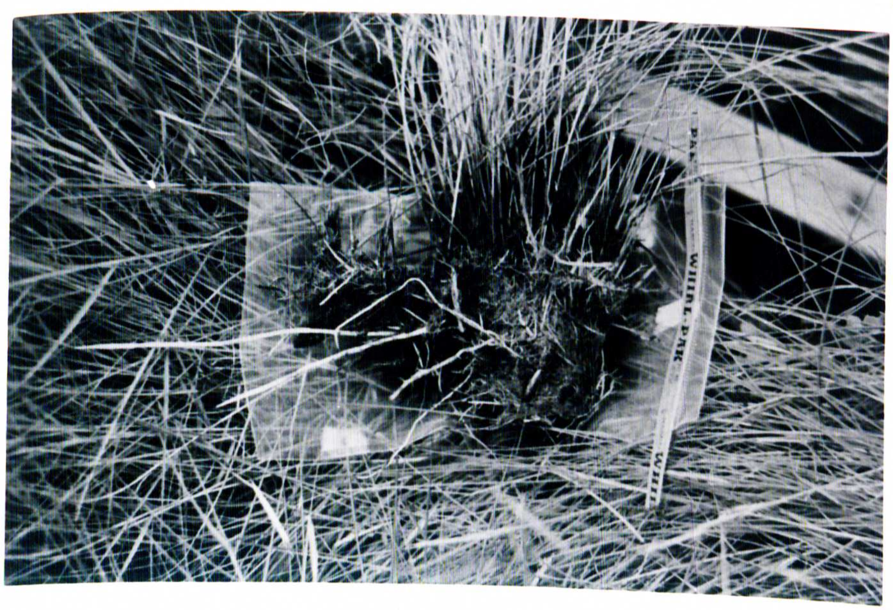

WHIRL-PAK

TABLE XXVI. ANALYSIS OF VARIANCE AND LINEAR CONTRAST OF YIELD IN THE CONTROL PLOTS (CP), CONTROL CAGES (CC) AND EXPERIMENTAL CAGES (EC) IN THE *SPARTINA PATENS*/ *DISTICHLIS SPICATA* ZONE

Analysis	Source of Variation	df	SS	MS	F	P less than
ANOVA	Within Cells	6	83382.687	13898.781	.911	.451
	Insects	2	25312.878	12656.439		
Linear Contrast	Within Cells	6	83392.687	13898.781		
	CC vs EC	1	522.667	522.667	.038	.853
	CP vs CC + EC	1	24790.213	24790.213	1.784	.230

TABLE XXVII. ANALYSIS OF VARIANCE AND LINEAR CONTRAST OF YIELD IN THE CONTROL PLOTS (CP), CONTROL CAGES (CC) AND EXPERIMENTAL CAGES (EC) IN THE *HIBISCUS MOSCHEUTOS* ZONE

Analysis	Source of Variation	df	SS	MS	F	P less than
ANOVA	Within Cells	6	133402.031	22233.672	1.822	.241
	Insects	2	81014.886	40507.443		
Linear Contrast	Within Cells	6	133402.031	22233.672		
	CC vs EC	1	1148.166	1148.166	.052	.828
	CP vs CC + EC	1	79866.726	79866.726	3.592	.107

same zone in the Rhode Island marsh (0.50% vs 0.34%, respectively). Also, the rate for *Typha angustifolia* at Horn Point is twice that of *T. latifolia* at Bissel Cove Marsh (1.0% vs 0.54%, respectively). In all, the total efficiency rate of Horn Point Marsh (0.60%) is more than twice that of Bissel Cove Marsh (0.24%). See Appendix A for caloric calculations.

Regression Analysis and Covariance Results

Regression analysis of height versus dry weight biomass was carried out for all zones for one year and all regression lines were compared to each other by covariance techniques. It was found that no significant difference in slope throughout the year could be detected at the 5% level of significance for height versus $\log_{10}$ weight values in all species except *Phragmites australis* and *Spartina alterniflora*. This means that all observations for the whole year could be combined, except in the *Phragmites australis* and *Spartina alterniflora* zones, to create one regression line that would describe the relationship of height to dry weight biomass for that entire year in that zone. Generating a line for each season is therefore not necessary (see Table XXIX). However, for *P. australis* and *S. alterniflora* two lines were generated and samples were grouped by seasons. The 1973 growing season and the following winter were joined in the first line and the 1974 growing season in the second for *P. australis*. For *S. alterniflora*, the very beginning of

TABLE XXVII. PRODUCTIVITY OF EMERGENT VEGETATION AT HORN POINT MARSH

				Aboveground production at end of growing season, 1974				
Species	Area m^2	Total Solar Radiation[a] (Kcal yr^{-1})	Visible Radiation[b] (Kcal yr^{-1})	g dry weight m^2	Kcal g	Kcal m^2 yr^{-1}	Kcal yr^{-1}	% Efficiency[c]
Phragmites australis	9.5×10^2	11.9×10^8	5.4×10^8	979	4.5	4.4×10^3	4.2×10^6	0.7
Spartina alterniflora	6.0×10^3	7.5×10^9	3.4×10^9	475	4.1	1.9×10^3	11.4×10^6	0.34
Amaranthus cannabinus	6.0×10^3	7.5×10^9	3.4×10^9	210	3.5	7.4×10^2	4.4×10^6	0.13
Spartina alterniflora/ Amaranthus cannabinus	6.0×10^3	7.5×10^9	3.4×10^9	777	3.8	3.0×10^3	18.0×10^6	0.53
Hibiscus moscheutos	11.5×10^3	14.4×10^9	6.5×10^9	445	4.4	2.0×10^3	2.3×10^6	0.35
Spartina patens/ Distichlis spicata	12.3×10^3	15.4×10^9	6.9×10^9	622	4.5	2.8×10^3	34.4×10^6	0.50
Typha/Hibiscus - *Typha angustifolia*	8.7×10^2	10.9×10^8	4.9×10^8	1304	4.4	5.7×10^3	4.96×10^6	1.0
Typha/Hibiscus - *Hibiscus moscheutos*	8.7×10^2	10.9×10^8	4.9×10^8	137	4.4	0.6×10^3	5.2×10^5	0.11
Typha/Hibiscus	8.7×10^2	10.9×10^8	4.9×10^8	1442	4.4	6.3×10^3	5.5×10^6	1.12
Total	31.6×10^3	39.5×10^9	17.8×10^9				106.4×10^6	0.60

[a]Eppley 180° Pyrheliometer, Salisbury, Md.: 12.5×10^5 Kcal/m yr^{-1}

[b]45% of Total (Reifsnyder and Lull, 1965)

[c](Kcal yr^{-1}/visible radiation) (100)

TABLE XXVIII. PRODUCTIVITY OF EMERGENT VEGETATION AT HORN POINT MARSH

				Aboveground production at end of growing season				
Species	Area m^2	Total Solar Radiation[a] (Kcal yr^{-1})	Visible Radiation[b] (Kcal yr^{-1})	g dry weight m^2	Kcal g	Kcal m^2 yr^{-1}	Kcal yr	% Efficiency[c]
Phragmites australis	9.5×10^2	11.9×10^8	5.4×10^8	979	5.8	5.7×10^3	5.4×10^6	1.0
Spartina alterniflora	6.0×10^3	7.5×10^9	3.4×10^9	475	4.7	2.2×10^3	13.2×10^6	0.39
Amaranthus cannabinus	6.0×10^3	7.5×10^9	3.4×10^9	210	3.3	6.9×10^2	4.1×10^6	0.12
Spartina alterniflora/ Amaranthus cannabinus	6.0×10^3	7.5×10^9	3.4×10^9	777	4.0	3.1×10^3	18.6×10^6	0.55
Hibiscus moscheutos	11.5×10^3	14.4×10^9	6.5×10^9	445	6.0	2.7×10^3	31.1×10^6	0.48
Spartina patens/ Distichlis spicata	12.3×10^3	15.4×10^9	6.9×10^9	622	6.1	3.8×10^3	46.74×10^6	0.68
Typha/Hibiscus - Typha angustifolia	8.7×10^2	10.9×10^8	4.9×10^8	1304	8.2	10.7×10^3	9.3×10^6	1.9
Typha/Hibiscus - Hibiscus moscheutos	8.7×10^2	10.9×10^8	4.9×10^8	137	8.2	1.1×10^3	9.6×10^5	0.20
Typha/Hibiscus	8.7×10^2	10.9×10^8	4.9×10^8	1442	8.2	11.8×10^3	10.3×10^6	2.10
Total	31.6×10^3	39.5×10^9	17.8×10^9				139.7×10^6	0.78

[a] Eppley 180° Pyrheliometer, Salisbury, Md.: 12.5×10^5 Kcal/m^2 yr^{-1}

[b] 45 % of Total (Reifsynder and Lull, 1965)

[c] (Kcal yr^{-1}/visible radiation) (100)

CORRECTION: SEE BACK COVER 56 DRC.

the 1974 growing season (April, 1974) was significantly different in slope (functional relationship of height and biomass) and elevation (mean biomass) than all other times of the year. The elevations were also found to be significantly different in the Spartina patens/Distichlis spicata and P. australis zones and the two lines generated for P. australis and S. alterniflora coincide the difference in means with the difference in slopes.

Transforming X or Y or both to $\log_{10}$ values did not significantly increase the R^2 value for each sample period in each species. But when all the data points for a given species are grouped together and analyzed by covariance techniques using $\log_{10}$ values of Y (weight), the R^2 value is significantly increased. The R^2 values and the regression equations in Table XXIX have been generated with $\log_{10}$ values and are based on a whole year's data except for the above mentioned species.

Transplants

All of the transplants of the Spartina patens/Distichlis spicata rhizome cubes survived in the autoclaved substrate which was returned to the trenches. It was begun on August 2, 1973 and three cubes were harvested February 2, 1974, May 4, 1974 and August 2, 1974. The average fresh weight and dry weight standing crop for each month was determined (Table XXX) and a one-way ANOVA of the net gain in fresh weight for each month indicates that all three means are significantly different from each other at the 1% level of

TABLE XXIX. REGRESSION EQUATIONS ($\hat{Y} = Y + b(X-\bar{X})$) AND CORRELATION COEFFICIENTS OF HEIGHT (CM) VERSUS LOG_{10} DRY WEIGHT BIOMASS FOR THE DOMINANT PRODUCERS AT HORN POINT MARSH

Species	Regression Equation*
Spartina patens/ Distichlis spicata	$\hat{Y} = 2.4906 + .0200(X - 40.76)$ $R^2 = .66$
Spartina alterniflora	$\hat{Y} = 2.5343 + .0053(X - 99.73)$ $R^2 = .27$ $\hat{Y} = .9830 + .1286(X - 16.4)$ $R^2 = .83$
Amaranthus cannabinus	$\hat{Y} = 1.7420 + .0202(X - 71.74)$ $R^2 = .61$
Hibiscus moscheutos	$\hat{Y} = 2.4814 + .0087(X - 109.90)$ $R^2 = .84$
Phragmites australis	$\hat{Y} = 2.1129 + .0082(X - 207.63)$ $R^2 = .96$ $\hat{Y} = 2.8562 + .0025(X - 245.50)$ $R^2 = .87$
Typha/Hibiscus *Typha angustifolia*	$\hat{Y} = 2.4472 + .0133(X - 153.91)$ $R^2 = .91$
Typha/Hibiscus *Hibiscus moscheutos*	$\hat{Y} = 1.4637 + .0165(X - 81.71)$ $R^2 = .78$

* Equations based only on slopes, differences in mean not included

significance (see Table XXXI). Linear contrasts of the three means indicate, however, that only May is significantly different from August at the 1% level while February is significantly different from the other two only at the 5% level. Figure 3 shows the amount of growth of transplants after 12 months.

An analysis of variance of the dry weight standing crop of rhizome material reveals that the three means are significantly different at the 5% level of significance (see Table XXXII) but linear contrast demonstrate that February is nonsignificantly different from May at the 5% level while August is significantly different from February and May at the 5% level.

The linear contrasts for both the fresh and dry weight standing crops were designed to test for significant differences between the beginning and end of the experiment and the test selections were based on the results.

In any event, an estimate of the shoot:root ratio and a projection of the underground biomass to an area basis is possible. A single cube is 2.5 cm x 2.5 cm on each side and 5.0 cm deep. Thus, the top surface area is 6.25 cm^2 and this means 1600 cubes equal one square meter of surface area in the marsh. The net gain in dry weight of underground biomass from August 2, 1973 to August 2, 1974 was 6.22 $\pm$ 1.69 (S.E.) grams per cube on the average with the dry weight of the 1973 biomass being estimated as 13.4% of the fresh weight. This yields 9,952 grams dry weight/m^2 with an estimated

TABLE XXX. DRY WEIGHT, FRESH WEIGHT, AND NET GAIN IN FRESH WEIGHT MEANS (IN GRAMS) WITH ONE STANDARD DEVIATION AND STANDARD ERROR FOR UNDERGROUND BIOMASS IN THE *SPARTINA PATENS*/*DISTICHLIS SPICATA* ZONE IN FEBRUARY, MAY, AND AUGUST IN 1974

	Dry Weight			Fresh Weight			Fresh Weight Gain		
Date	Mean	S.D.	S.E.	Mean	S.D.	S.E.	Mean	S.D.	S.E.
February	7.23	0.84	0.48	53.5	6.14	3.55	1.66	2.84	1.64
May	7.83	2.44	1.41	61.0	12.8	7.37	9.77	8.21	4.74
August	14.8	4.19	2.42	104.0	23.9	13.8	39.8	14.5	8.36

standard error of $\pm$ 2,704.0. On a total area basis, the *S. patens*/*D. spicata* zone covers 12,334 m^2 and this means a dry weight underground production in the top 5 cm of the mat of 122.7 $\pm$ 33.4 (S.E.) metric tons per year. The average live shoot biomass per m^2 on July 21, 1974 was 622 g. This means that the shoot:root ratio for a whole year's growth of underground biomass and the yearly peak in above ground biomass was 622:9952 or 1:16 g dry weight.

TABLE XXXI. ANALYSIS OF VARIANCE AND LINEAR CONTRAST FOR NET GAIN IN FRESHWEIGHT OF <u>SPARTINA PATENS/DISTICHLIS SPICATA</u> ROOT AND RHIZOME TRANSPLANTS IN FEBRUARY, MAY AND AUGUST OF 1974

Analysis	Source of Variation	df	SS	MS	F	P less than
ANOVA	Within Cells	6	570.120	95.020	12.720	.007
	Gain	2	2417.220	1208.610		
Linear Contrast	Within Cells	6	570.120	95.020		
	May vs August	1	1350.000	1350.000	14.208	.009
	Feb. vs May & Aug.	1	1067.220	1067.220	11.232	.015

TABLE XXXII. ANALYSIS OF VARIANCE AND LINEAR CONTRAST FOR DRY WEIGHT STANDING CROP OF ROOT AND RHIZOME TRANSPLANTS OF THE *SPARTINA PATENS*/*DISTICHLIS SPICATA* ZONE IN FEBRUARY, MAY AND AUGUST OF 1974.

Analysis	Source of Variation	df	SS	MS	F	P less than
ANOVA	Within Cells	6	48.520	8.087	6.623	.030
	Gain	2	107.120	53.560		
Linear Contrast	Within Cells	6	48.520	8.087		
	February vs May	1	.540	.540	.067	.805
	Aug. vs Feb. & May	1	106.580	106.580	13.180	.011

DISCUSSION

There are not many reports in the literature on the net productivity of salt marsh species which span two growing seasons and which include analysis of yearly variation, seasonal changes in rates of production, and changes in dominance of plant species in terms of production. This is partly due to logistic problems of sequential harvesting and also to the fact that many marsh systems that have been studied are generally large marshes in which the dominant producer is clearly and easily defined, covers the largest percentage of the marsh, and usually never changes (Schelske and Odum, 1961; Teal, 1962; Stroud and Cooper, 1969; Udell et al., 1969; Williams and Murdoch, 1972; Eleuterius, 1972; Gallagher and Reimold, 1973; and Nixon and Oviatt, 1973b). See Table XXXIII. However, since Horn Point Marsh is very heterogeneous and small the production energetics are more complicated and less clearly defined.

Standing Crop and Height Values

Schelske and Odum (1961) stated that there are 5 factors responsible for the high productivity which is typical of Georgia's estuaries - tidal influences, abundant nutrients, rapid turnover and conservation of nutrients, three types of primary producers, and year-round production.

TABLE XXXIII. PERCENTAGE OF AREA COVERED BY EMERGENT GRASSES IN SOME ATLANTIC COAST SALT MARSHES

Location	Tall *Spartina alterniflora*	Other *Spartina alterniflora*	Mixed *S. patens*/ *D. spicata*
Rhode Island (Nixon & Oviatt, 1973b)	7	72	19
Long Island (Udell et al., 1969)	10	67	23
Maryland (this study)	14	0	29
North Carolina (Stroud & Cooper, 1969)	6	54	-
Georgia (Teal, 1962)	20	80	0

In Georgia, at Sapelo Island, the marshes are exposed to large tides with regular flooding, high salinities, and produce two crops a year of Spartina alterniflora. These factors combine to help produce a large standing crop.

At Horn Point Marsh, however, the standing crop is comparatively small and the unadjusted standing crop estimates taken in 1973 and 1974 appear to be lower than most of the other estimates for the Atlantic Coast for every species sampled. Average peak values for Phragmites australis in 1973 and 1974 (892 g/m^2) are lower than all other estimates (Harper, 1918; Johnson, 1970) and the average Spartina patens/Distichlis spicata standing crop (628 g/m^2) is about the same (680 g/m^2) as that reported by Nixon and Oviatt, (1973b) and higher than that reported by Udell (1969) but still lower than the figures from more southern states (see Table I). However, our estimate is higher than the average for the entire Atlantic Coast (610 g/m^2). The two year average of peak standing crop at Horn Point Marsh for the Spartina alterniflora/Amaranthus cannabinus zone (676 g/m^2) ranks within the lower portion of the range of all previously published standing crop values in the Chesapeake Bay region for Maryland, Virginia, and Delaware (427-1725 g/m^2) (Morgan, 1961; Wass & Wright, 1969; Keefe & Boynton, 1973; Mendelssohn & Marcellus, 1971). In the more southern states however, the estimates rank about the same as those for Medium S. alterniflora but far less than those for Tall S. alterniflora. For New Jersey and northward the estimates for S. alterniflora range from 300-1592 g/m^2 with our estimates being considerably lower than most. Overall, our estimate of 676 g/m^2 for S. alterniflora is only half the average for medium and tall height ecophenes of this species on the Atlantic and Gulf Coasts (1040 g/m^2).

The 1973-74 average value of the Typha/Hibiscus zone (1110 g/m^2) is higher than for Typha angustifolia (985 g/m^2) or Hibiscus moscheutos (184 g/m^2) treated individually (see Tables IX-XI). Our estimate for T. angustifolia is considerably lower than the value reported by Harper (1918) and is in the very lower portion of the range reported by Flemer et al., (1973). There are no productivity figures in the literature to which our Hibiscus moscheutos estimate (516 g/m^2) can be compared but at Horn Point Marsh it produces more when it is not growing mixed with Typha angustifolia.

Average height estimates for Phragmites australis at Horn Point (228 cm) are about the same as those reported by Bayly and O'Neill (1972) in Ontario, Canada (265 cm) while our Spartina patens/Distichlis spicata height measurements (56 cm) rank considerably higher than those for Long Island. Udell (1969) reported a mean height of 25 cm for S. patens and 33 cm for D. spicata. Our average reading for Spartina alterniflora is 117 cm which falls in the range of the New England estimates (112-127 cm) for Tall S. alterniflora but short of the southern estimates (140-300 cm).

These low productivity values are probably due more to the physical environment at Horn Point Marsh than to any other reason. Salinity is low throughout the brackish marsh ranging from 0-15 ppt at different times of the year in different parts of the marsh. There is no year-round production (two crops a year) except for the very small amount of S. patens and S. alterniflora that remains alive through the winter. Probably most important of all however, is the very low flooding in the marsh and the intermittent tides. Much of this is due to the "sill effect" of the concrete spillway which can influence the tidal level of the marsh. For this reason freshwater stream drainage is as important if not more important than tidal influence in at least the upper reaches of the marsh. Comparatively speaking, Horn Point Marsh is subjected to much lower salinity and much less tidal influence than marshes from the southeastern Atlantic Coast. The tides in salt marshes of Georgia and South Carolina are over 2 meters and occasional spring tides exceed 3 meters (Hoese, 1967). Bissel Cove Marsh in Rhode Island (Nixon and Oviatt, 1973b) had higher salinities (1-28 ppt) but had a similar "sill effect" as Horn Point due to a large culvert at the marsh entrance, which truncated the tidal range to 27 cm. This similar tidal range may account for the similar productivity values at Bissel Cove and Horn Point.

Taylor (1939), Adams (1963), Stalter and Batson (1969), Gosselink (1970), Mooring et al. (1971), and Good (1972) state that Spartina alterniflora grows best in low salinity or freshwater conditions. Woodhouse, Seneca, and Broome

(1974) also demonstrated by regression techniques that salinity of the soil solution is negatively associated with yield in S. alterniflora and therefore growth decreases with increasing salinity. Stalter (1973) reported that S. alterniflora can tolerate the widest range of salinity and the longest period of flooding but prefers the low marsh, which is not necessarily the highest salinity region of the marsh. As salinity levels rise to that of the open ocean and higher, the rate of respiration increases and the rate of photosynthesis decreases in S. alterniflora and less food is available for growth of the plant (Luce and Queen, 1971). Best growth is therefore found in moderately saline environments. The question is, therefore, why is the productivity of S. alterniflora at Horn Point Marsh so low if low salinity is essential for best growth?

First of all, the S. alterniflora zone is quite diversified due to the low salinity (see Table II) and thus there is a great deal of interspecific competition. For example, at certain times of the summer Amaranthus cannabinus production is 30-50% of the S. alterniflora production. In addition, plant species that are adapted to freshwater would probably become dominant in freshwater conditions in a salt marsh. Also, in seedling experiments with different geographical populations of S. alterniflora, Seneca (1974) demonstrated that seedlings of the southern populations (North Carolina and southward) had stouter culms and wider leaf blades than seedlings of northern populations with the aerial biomass distributed amongst fewer culms in the southern populations. Overall, the more southern populations have a longer growing season and produce more than the northern populations and such a latitudinal gradient may play a part in the productivity of S. alterniflora at Horn Point Marsh (see Keefe, 1972).

However, probably the most important factor influencing production of S. alterniflora is the duration and depth of flooding. Salt damage can occur, especially to seedlings, at times of extended low water that coincide with periods of warm clear weather (Woodhouse, Seneca, and Broome, 1974). More importantly, Steever (1972) hypothesized that net productivity is positively correlated with increasing tidal amplitude. At marshes in Connecticut north of Long Island Sound, in a tidal range of 2.7 - 7.9 ft., S. alterniflora was sampled at 8 different locations and an increase in mean tidal range at the different sites yielded an increase in net productivity ($R^2 = +.963$). Thus our small tidal range of 49 cm is not beneficial to the marsh's productivity since there is little or no energy subsidy by this minimum of tidal action but the plants are still exposed to rigorous osmoregulatory stresses.

It seems possible that the intermittent tides may reduce the nutrient supply and make some nutrients limiting. Adams (1963) showed that S. alterniflora grown in freshwater without an iron (Fe) supplement soon becomes very chlorotic As a matter of fact, the plants at Horn Point often seem very yellow, especially near the peak of the growing season. Valiella and Teal (1974) postulate that nutrients, such as nitrogen, are brought into salt marshes largely by tidal waters and that salt marshes are therefore important in removing dissolved nutrients, with these dissolved nutrients being incorporated into the vegetation and eventually exported as organic detritus. This hypothesis may be supported by the fact that S. alterniflora plants in the lower part of their vertical range have a higher percentage of nitrogen in the plant tissues than plants from the higher part of the vertical range (Queen, 1971).

The fact that most of the nutrients in a salt marsh come from tidal waters rather than other sources within the marsh is still a point of controversy but it provides a possible explanation for the low productivity of Spartina alterniflora at Horn Point Marsh. Therefore, tidal inundation is probably the limiting factor most affecting S. alterniflora productivity.

On the other hand, the other vegetation types are probably not so dependent on regular flooding as is Spartina alterniflora. Spartina patens occupies higher and drier areas of the marsh. Cooper (1969) reports that S. patens has a wider range of salt tolerance for high germination than other species, even S. alterniflora. This wider salt tolerance for germination could be one of the reasons that in 1973 S. patens/D. spicata produced more than S. alterniflora at Horn Point, especially since 10 extreme flood tides occurred during the growing season. However, conflicting data on D. spicata has been reported in regard to salinity tolerances. Barbour and Davis (1969) report that on the Pacific Coast it grows best at 0.1% salinity while Adams (1963) states it grows best at 1.0% as opposed to 0 or 2% salinity in North Carolina. Nonetheless, productivity in this zone is more equivalent to other areas along the Atlantic Coast than any other zone at Horn Point, possibly because the S. patens/D. spicata zone is well-suited to the low salinity and low flooding conditions.

As previously mentioned, data from the Town Point weather station located 3.5 kilometers from Horn Point Marsh reveals that 10 extreme high tides (higher than normal for that time of year) occurred between March and October in 1973 while none occurred in the same time period in 1974. This high number of high tides that reached the Phragmites australis and Typha/Hibiscus zones in the upper parts of the marsh in 1973 were probably detrimental to their growth. This fact, coupled with the very small size of the zones, accounts for the significantly lower production estimates for these zones in 1973.

Daily Rates

Estimates of daily rates of production of salt marsh species are not too common, but in general the adjusted estimates for Horn Point are lower than most that have been reported. In New Jersey, Squiers and Good (1974) reported that *Spartina alterniflora* accumulated at a daily rate of 8 g/m^2 in the spring, 26 g/m^2 in early summer, -13 g/m^2 in late summer and -1 g/m^2 in the fall. For a Delaware *S. alterniflora* salt marsh Morgan (1961) reported a growth rate of 5.32 g/m^2 per day. Boyd (1971) reported daily rates of 2.4 - 7.1 g/m^2 for *Typha latifolia* between March 24 - April 23 and 7.9 - 21.5 g/m^2 for April - June. Overall, at the peak of the season he reported a rate of 4.4 - 10.3 g/m^2 per day for 5 different sites. Boyd (1971b) also reported daily rates for *Juncus effusus* of 9.0 g/m^2 for February - May, 14.6 g/m^2 for October 3 - October 31, and 11.4 g/m^2 for August 29 - November 23. In Mississippi, Gabriel and de la Cruz (1974) report daily growth rates of a vegetationally mixed marsh as $<$.833 g/m^2 in winter, 1.33 - 2.33 g/m^2 in spring, 3 - 4 g/m^2 in late summer, and approximately 1 g/m^2 in autumn.

Even fewer studies of yearly variation in the rates of production, or even standing crop, of salt marsh species have been made. This study shows that there is significant variation in some species. It is not too surprising to see that *Typha* and *Phragmites* have significant variations because they are essentially freshwater plants. Their productivity could be adversely affected by variations in salinity and the salinity in these zones depends mostly on the tides. As previously stated, several high tides occurred in 1973 but none in 1974. Also, the average precipitation for January to September in 1974 (3.91 inches) was greater than the average amount for March to December in 1973 (3.34 inches). Thus the difference in production from year to year could be due to differences in the number and extent of large storm tides that flood the marsh and to the amount of fresh-water run-off from precipitation that occurs in the higher zones of the marsh. Good (1972) expresses the opinion that the highest production for a given species is associated with the smallest fluctuation in salinity and vice versa. This fluctuation is probably the best explanation for the variation in these two zones.

The _Spartina patens_/_Distichlis spicata_ zone also exhibited significant yearly variation but it does not seem likely that variation in salinity would cause it in this zone since it is probably a facultative halophyte and exhibits a high tolerance for substrate salinity (Seneca, 1969 & 1972). More likely it is caused by variations in nutrient supply which are probably tied in with fluctuations in the tides.

Weighted Production Values

The _Spartina patens_/_Distichlis spicata_ zone consistently is the single most important producer in terms of areally weighted and adjusted standing crop and net biomass even though it is not the largest producer in terms of unweighted monthly net biomass or daily rates (see Tables XII - XVIII). This zone repeatedly produced more than the other zones and accounted for the largest percentage of production throughout the 16 month period. Only on October 1, 1973 did _Hibiscus_ moscheutos ssp. moscheutos produce more weighted standing crop, and only in June, 1974 did it produce more weighted net biomass. The main reason for this is that the S. patens/D. spicata zone is the largest zone in the marsh and despite the fact that it ranks only fourth in unadjusted standing crop (628 g/m^2) behind Phragmites, Typha/Hibiscus, and S. alterniflora, it is 14 times larger than either Phragmites or Typha/Hibiscus and is twice as large as S. alterniflora. The Hibiscus moscheutos zone ranks second in importance in weighted and adjusted standing crop and net biomass production even though it ranks fifth in original standing crop because of its size. This trend in production can be seen for all the zones since in total marsh production the size of the zone is more important than the original standing crop or even the unweighted adjusted standing crop and net biomass.

Net Primary Production

Unexpectedly, the control plots yielded higher standing crop estimates than the experimental plots in the grazing exclosure experiment for the Spartina patens/Distichlis spicata zone. It seems possible that the reduced light intensity may have created this response since the semi-enclosed cages had a lower yield than the controls and the totally enclosed cages had an even lower yield. This being the case, however, it seems logical to assume that a synergistic effect of reduced light intensity and predation would induce the lowest amount of production but this was not so. Due to the presence of toxic alkaloids in marsh plants, A. A. de la Cruz (1974) states that very little grazing by herbivores occurs and 90% of the production is decomposed into detritus.

Plant communities which utilize the C_4 or Hatch-Slack photosynthetic pathway are usually more strongly based on a detritus as opposed to grazing food web and salt marshes are a good example (Caswell et al., 1973). If this is the situation at Horn Point Marsh, then the decrease in production in the cages could simply be due to decreased light intensity and possibly increased temperatures over the plants with predation by herbivores playing little or no part at all in the production estimates. Also, Caswell et al. (1973) hypothesized that C_4 plants are a poorer food source for herbivores than C_3 plants and that herbivores therefore tend to avoid feeding on C_4 species. Most marsh plants, such as *S. alterniflora* and *S. patens*, are C_4 plants and this could provide another explanation for this unusual result.

Voracious grazing by chewing insects is typical of the *Hibiscus moscheutos* zone at Horn Point (see Figure 2) and the plants responded in an expected manner in the grazing exclosure experiment. Surprisingly, it appears that the *Hibiscus* plants thrived on the reduced light intensity. The plants in the experimental cages were far superior to both sets of controls in health, appearance, and stature but the large variances of biomass in controls and experimental units prevented conclusive demonstration of statistically significant differences. Spray damage from the malathion coupled with the increased ambient temperature and decreased light intensity may have created a synergistic effect detrimental to yield and perhaps explains why the experimental cages produced less than the control cages. Also, the one-way anova may be misleading since the linear contrasts demonstrate that the control plot is essentially significantly different at the 10% level from the other plots (see Table XXVII).

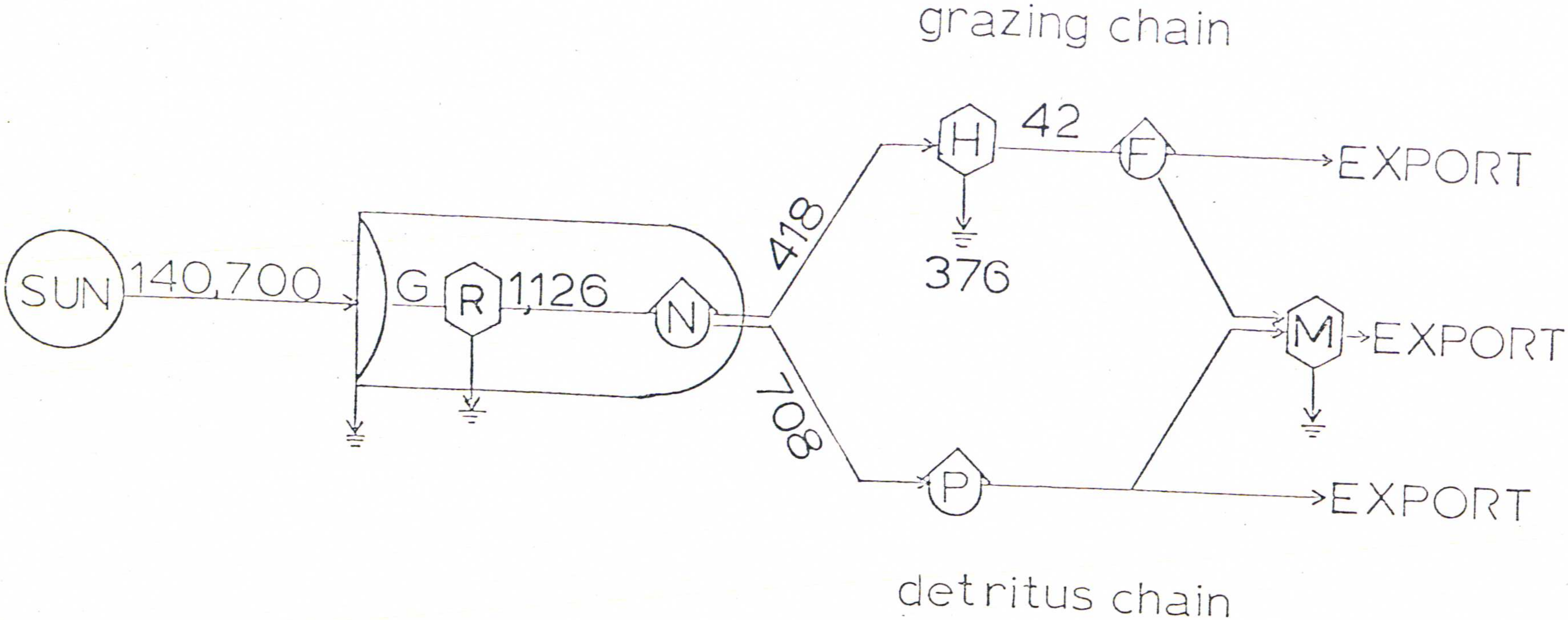
In general, grazing doesn't seem to be an influential factor affecting the productivity of the salt marsh species *Spartina patens* and *Distichlis spicata*, and probably isn't for the species *S. alterniflora* either (de la Cruz, 1974). Therefore very little energy flows through the grazing chain in the salt marsh. But it seems likely that the grazing chain plays a more important role in the productivity of the freshwater *Hibiscus* marsh. I feel certain that if a larger sample size had been employed, a significant difference in yield would have been detected. It appears that, at Horn Point Marsh, more energy flows through the grazing chain in the freshwater marsh than in the salt marsh and tends to confirm the 5% level of assimilation reported by Teal (1962).

Solar Radiation

The monthly average of incident solar radiation for June and July, 1974 was 140,700 Kcal/m^2 per month (measured at the University of Maryland Vegetable Farms, Salisbury, Md.). In the *Hibiscus moscheutos* fresh marsh, 0.8% (1,126 Kcal/m^2 per month) of this solar energy was assimilated as NPP with 37% (418 Kcal/m^2 per month) of the NPP going to the grazing food chain and 63% (708 Kcal/m^2 per month) going through the detritus chain. See Figure 4. For the *Spartina patens/Distichlis spicata* zone in the brackish marsh, 0.50% (747 Kcal/m^2 per month) of the sun's energy ended up as NPP with just about all of it going into the detritus chain. See Figure 5.

The NPP assimilation rate in the fresh marsh of 0.8% is higher than the rate of 0.5% reported by Odum (1971) under average favorable conditions for productivity values in general, but the assimilation rate for the brackish marsh (0.50%) is about average. It is important to note that the NPP in the fresh marsh is 60% higher than that of the brackish marsh, probably due to the greater amount of respiration required to maintain the proper osmotic balance in the saline conditions (Teal, 1962). Due to the irregular tides there is probably little energy subsidy by tidal action, another reason why the fresh marsh assimilates twice that of the brackish marsh. However, in Georgia, Teal (1962) reports an estimated NPP for *Spartina alterniflora* to be 1.4% of incident solar radiation, an even higher estimate than that of our fresh marsh. This high assimilation rate in the salt marsh could be partly due to the higher productivity of southern marshes. Bray (1962) reports an NPP value of 0.93%

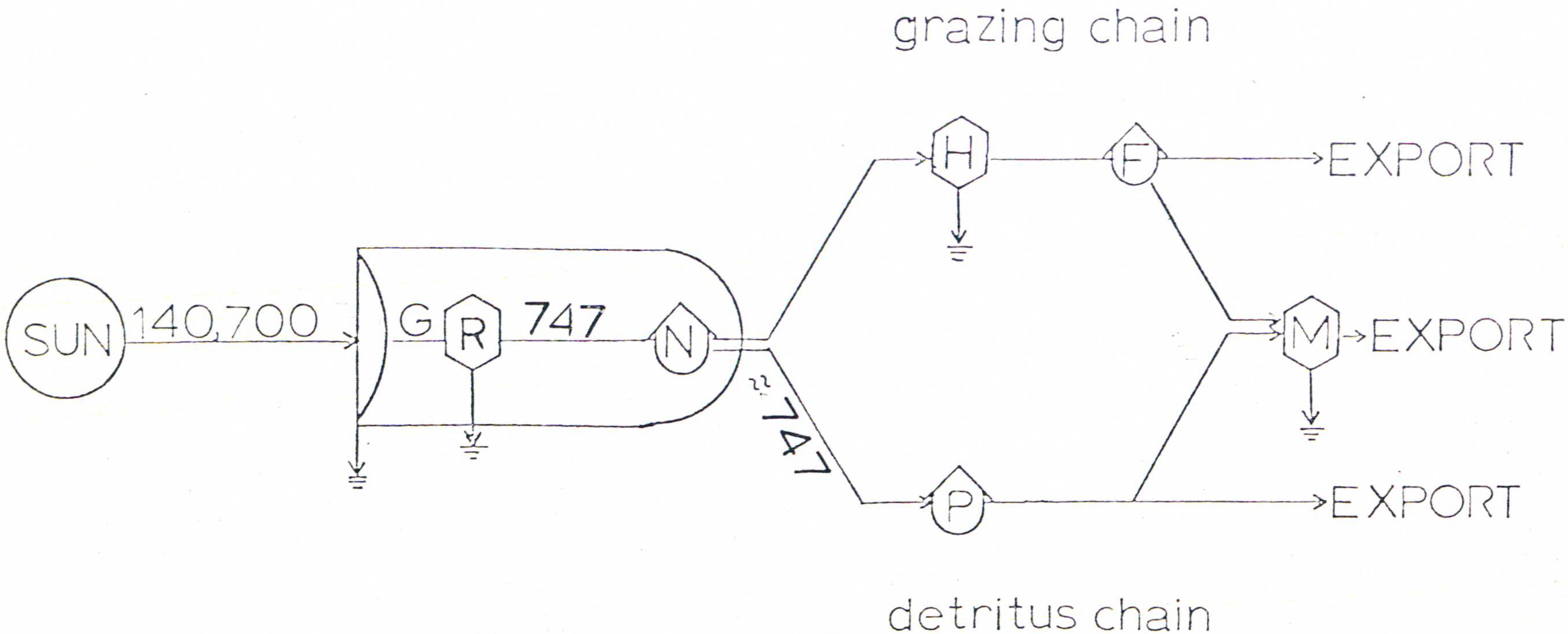
Figure 4. Energy flow in Kcal/m^2 per month for June-July, 1974 in the *Hibiscus moscheutos* fresh marsh showing the rate of storage of organic matter in plant tissues in excess of plant respiration (NPP) and the amount of energy moving through the grazing and detritus food chains for Horn Point Marsh. Key to compartments: G = Gross Primary Production (GPP), N = Net Primary Production (NPP), H = Herbivores, F = Faunal Detritus, P = Phyto-Detritus, M = Microconsumers, R = Respiration



FRESH MARSH

79a

Figure 5. Energy flow in Kcal/m^2 per month for June-July, 1974 in the _Spartina patens_/_Distichlis spicata_ brackish marsh showing the rate of storage of organic matter in plant tissues in excess of plant respiration (NPP) and the amount of energy moving through the grazing and detritus food chains for Horn Point Marsh. Key to compartments: G = Gross Primary Production (GPP), N = Net Primary Production (NPP), H = Herbivores, F = Faunal Detritus, P = Phyto-Detritus, M = Microconsumers, R = Respiration



BRACKISH MARSH

for a freshwater *Typha* marsh, higher than both the fresh and brackish marsh.

As far as food web dynamics are concerned, the food chains in the brackish marsh follow the typical pattern displayed in the literature. Teal (1962) reports that 4.6% of the NPP is utilized in the grazing food chain of a Georgia *Spartina alterniflora* marsh and Bray (1962) reports that 1.0% of the NPP in the *Typha* marsh is utilized by grazers. At Horn Point, grazing is negligible and utilization is essentially 0.0% in the brackish marsh. The fresh marsh is completely different, however, and grazing is heavy with 37% of the NPP being utilized by grazers. This is an extremely high value for predation and it tends to underscore the importance of freshwater *Hibiscus* marshes in providing food and shelter for the secondary producers of the marsh ecosystem.

Regression Analysis and Covariance Results

As previously mentioned, few regression analyses of height versus dry weight biomass have been reported in the literature and none that cover an entire year and deal with different seasons of the year. Stroud (1972) made a study of use of regression analysis to determine if one concentrated sampling effort can be done in lieu of sampling throughout the growing season.

The regression equations in Table XXVIII show that the regression coefficients in every zone are positive as one would expect during times of growth and that the largest coefficient (b) is found in the species Amaranthus cannabinus (.0202) and the Spartina patens/Distichlis spicata zone has the second largest (.0200) and Hibiscus from the Typha/Hibiscus zone the third largest coefficient (.0165). The highest correlation coefficient (R^2 = .96) occurred in the first Phragmites australis line, the second highest in the Typha/Hibiscus zone for T. angustifolia (R^2 = .91) and the third largest in the second P. australis line (R^2 = .87).

The need for generating two regression lines for Phragmites australis is due to the significant difference in slope between the two growing seasons. The means were also significantly different between the two growing seasons and therefore the means and slopes were grouped identically for the analysis. For Spartina alterniflora the slope is significantly higher and the average live biomass is significantly lower at the very beginning of the growing season than it is at any other time of the year. The elevations (means) in the Spartina patens/Distichlis spicata zone were also significantly different due to the April, 1974 reading which means that the biomass at this time of the year is significantly less than at other times for this zone.

In comparison, some of our R^2 values are as high or higher than other values in the literature. For instance, Phragmites australis (+.96,+.87), Typha angustifolia (+.91) and Hibiscus moscheutos (+.84,+.78) have very good positive correlations between height and $\log_{10}$ weight and these regression equations would probably make good predicters of standing crop for these species in the Chesapeake Bay region. The R^2 values for the other species are intermediate to the other values in the literature but are sufficiently high to be considered important in describing the relationship of height to $\log_{10}$ weight for these species. The poorest correlation ($R^2 = .27$) occurs in the species S. alterniflora for the line encompassing all parts of the year except the very beginning of the growing season.

Transplants

The ANOVA and linear contrasts indicate that there is a significant increase in the net gain of fresh weight in the transplants. There is a significant gain in fresh weight at the 5% level between February and May and an even more significant gain at the 1% level between May and August. It appears that during the ninth to twelfth months of the experiment, which happens to span the summer growing season, the greatest increase in net fresh weight occurred. This fact is also supported by the knowledge that the dry weight standing crop values for February and May are nonsignificantly different but that the August rhizome standing crop is significantly different from the other two. Thus it seems the greatest subterranean production occurred during the summer growing season. In concurrence with this observation, Seneca (1974b) reports that high temperatures and long days, which are characteristic of summer months, are the most optimal conditions for high productivity of roots, rhizomes, stolons, and upright culms in Spartina patens.

This increase in productivity in the summer could be coincidental or be an artifact of the transplanting in as much as there may be a lag period in growth due to adjusting to the transplantation. In any event, root growth usually slows down as shoot growth increases in most plants because more energy is put into shoot production during the height of the growing season. These findings do not coincide with this way of thinking but I must stress the fact that this was a small experiment and by no means totally conclusive. Further work should be done on this subject for salt marsh species and a regular, consistent set of control samples of underground production are essential to an understanding of transplant productivity.

A. A. de la Cruz (1974b) reports a total dry weight biomass of 9 - 16 Kg/m^2 for below ground material of six types of marsh communities in Mississippi and our value of 9.95 Kg/m^2 falls in the lower part of this range. However, our estimate is 16 times greater than the aerial production and de la Cruz reports his estimates of below ground material to be only 7 - 9 times greater. This larger ratio at Horn Point Marsh is due to the much lower aerial productivity than that which is found in Mississippi (622 vs 1922 g/m^2, respectively).

SUMMARY

This study was carried out to determine yearly production for a Chesapeake Bay eastern shore salt marsh. Overall, the productivity in this marsh is lower than most other productivity estimates for the Atlantic and Gulf Coasts. The mean for *Spartina alterniflora* is only half the average for medium and tall height ecophenes for both coasts (1040 g/m^2) but the *Spartina patens/Distichlis spicata* zone peak value of 628 g/m^2 is slightly higher than the Atlantic and Gulf Coast average of 610 g/m^2. The lower production values for these zones and the other zones in the marsh are most likely due to variable low tides and variations in salinity. Determinations of yearly variation in production showed that the *S. patens/D. spicata*, *Phragmites australis*, and *Typha angustifolia* from the *Typha/Hibiscus* zones were significantly different between 1973 and 1974 in adjusted production.

Estimations of NPP showed that predation is not prevalent in the *S. patens/D. spicata* zone but it is in the *Hibiscus moscheutos* zone. NPP for the fresh marsh was 0.8% and for the brackish marsh 0.5% of incident solar radiation. In the fresh marsh 37% of the NPP went into the grazing chain while 63% went into the detritus chain. In the brackish marsh nearly 100% of the NPP went into the detritus chain.

Covariance analysis of height versus dry weight revealed no seasonal variation within each species which means all the estimates for an entire year may be clumped together for regression analysis except for *Phragmites australis* and *Spartina alterniflora*. These two species had significant differences in slope throughout different parts of the year and therefore two lines were generated for them. Means for the 12 month period were significantly different in the *Spartina patens*/*Distichlis spicata*, *P. australis*, and *S. alterniflora* zones. An experimental approach for estimating underground production in the *S. patens*/*D. spicata* zone involving transplantation of known weights of roots and rhizomes *in situ* and reharvesting at 3 month intervals yielded a significant increase in fresh weight net gain after 12 months. The shoot:root ratio for this zone is 1:16 g dry wt./m^2.

APPENDIX A

TABLE XXXIV. CALORIC VALUES FOR THE DOMINANT PRODUCERS AT HORN POINT MARSH

Species	1973 Kcal/g	1973 $\bar{X} \pm$ S.E.	1974 Kcal/g	1974 $\bar{X} \pm$ S.E.
Phragmites australis	4414 4366	4390 ± 24	4455 4456	4456 ± 0.5
Spartina alterniflora	4225 4297	4261 ± 36	4121 4118	4120 ± 1.5
Amaranthus cannabinus	3518 3637	3578 ± 60	3514 3449	3482 ± 33
Spartina alterniflora/ *Amaranthus cannabinus*		3919 ± 199		3801 ± 185
Hibiscus moscheutos	4223 4354	4289 ± 66	4262 4465	4364 ± 102
Spartina patens/ *Distichlis spicata*	4596 4575	4586 ± 11	4548 4427	4488 ± 61
Typha/*Hibiscus* *Typha angustifolia*	4488 4315	4383 ± 67	4503 4344	4424 ± 80
Typha/*Hibiscus* *Hibiscus moscheutos*	4285 4242	4264 ± 22	4372 4488	4430 ± 58
Typha/*Hibiscus*		4323 ± 44		4427 ± 57
Total		4250 ± 82		4252 ± 94

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